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ELECTRIC ELEVATORS

THEIR DESIGN, CONSTRUCTION, OPERATION AND MAINTENANCE

BY

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PREFACE TO THE SECOND EDITION

The first edition of this book was published during the rising tide of a building boom, out of which came some of the world's greatest commercial structures—the Empire State, Chrysler, Bank of Manhattan, Rockefeller Center, and other unprecedented office buildings. Plans and specifications also were drawn for others of even more imposing proportions. To meet demands for efficient and economical vertical transportation in these buildings required many changes in conventional elevator designs.

These new developments and changes in practice have justified a second edition. Chapter I has been greatly enlarged by descriptions of new developments. Chapters V, VIII, IX, XII, XIV, XV, XXIV, and XXV have been replaced by approximately 200 pages of new material. Two of the new chapters are on control, one on micro-leveling signal control, the other on car-switch operation with automatic landing. Car- and hoistway-door operators, signal systems, and selection of elevators—subjects not covered in the previous edition—have been treated in three chapters. An entirely new chapter on ropes is included, and the chapter on lubrication has been enlarged with new material on automatic guide-rail lubricators and guide-shoe gibs. A new chapter has also been added on double-deck-car elevators and two elevators operating in one hoistway. Additions have been made to other chapters, so that the new edition contains about 60 pages more than the old.

Appreciation is here expressed to the several companies and individuals who have helped to make this edition possible. Credits for specific data are given in the various chapters.

It is hoped that this edition has been made worthy of the appreciative reception accorded its predecessor.

THE AUTHOR.

NEW YORK CITY,
May, 1935.

PREFACE TO THE FIRST EDITION

Although the use of elevators dates back thousands of years and they have become an important factor in modern transportation systems, comparatively little has been published on their design, construction, operation and maintenance. As to the importance that the elevator has attained, it is estimated that in large cities as many passengers are carried on elevators as there are transported on the street-railway systems.

Electric passenger and freight elevators embrace a wide variety of types and forms. Space will not permit a description of all types, but in the first two chapters a sufficient number have been considered to give the reader a fairly comprehensive idea of the field and what may be expected in both direct-current and alternating-current applications. During the last ten years elevator designs have practically been revolutionized, and new designs are being put into service at frequent intervals. This makes it difficult to include in a book all the latest practice. However, automatic-leveling or automatic-landing types of machines with variable-voltage or other types of control systems, as in use today, will probably remain standard equipment for some time. For this reason, these systems have been treated at considerable length. The latest designs in elevator machines represent only a small part of those in use, so that, to meet these conditions, it has been deemed advisable to include in a general way all types from the old belt-driven machine to the high-speed automatic-leveling machine with signal control.

The brain and nervous system of the elevator machine may be said to be the control equipment and considerable space has been devoted to this subject. In dealing with this equipment, detailed information on circuits, operation and adjustments have been given rather than broad generalities. The impossibility of treating all types of controllers has been realized, and to compensate for this limitation, effort has been made to give the reader a good grounding in the fundamental principles of control equipment, so that any controller diagram may be

easily understood. To this end one chapter has been devoted to the fundamental principles of control, another to types of reversing switches and ten chapters to wiring diagrams of different type controllers.

Most of the material has appeared in *Power* at various times. Although this in the most part has been written by the author and appeared under his name or a non de plume, he wishes to express his appreciation to M. A. Myers, Electrical Engineer, the Maintenance Company, New York City; William Zepernick, Otis Elevator Company, Chicago, Ill.; Howard B. Cook, Electrical Engineer, Warner Elevator Manufacturing Company, Cincinnati, Ohio; Warren Hilleary, Superintendent, Royal Indemnity Company, New York City; Jacob Gintz, Jr., Chief Instructor, New York Electrical School; C. R. Calloway, Vice-President, The Gurney Elevator Company, New York City; W. F. Glasier, Cutler-Hammer Manufacturing Company, New York City; A. A. Gazda, Manager, Engineering Department, Kaestner & Hecht Company, Chicago, Ill.; E. B. Thurston, Chief Engineer, Haughton Elevator & Machine Company, Toledo, O.; E. M. Bouton and F. D. Lewis, Westinghouse Electric & Manufacturing Company, Pittsburgh, Pa., for their assistance in the preparation of this book. Where manufacturers have furnished photographs or diagrams, credit has been given in the text. The author also wishes to express his appreciation to Fred R. Low, Editor, and A. D. Blake, Associate Editor of *Power*, for their encouragement and the opportunity to make this book possible.

It is realized, that this book is not as complete as might be desired, but the demand for a work on modern elevators has made it appear advisable to make this information available rather than delay the publication until a more comprehensive work can be prepared. The rapid development in the art will undoubtedly justify a revised edition in a few years; in the meantime it is hoped that these efforts will serve a useful purpose.

THE AUTHOR.

NEW YORK CITY.

CONTENTS

ELECTRIC ELEVATORS

CHAPTER I

TYPES OF MACHINES—DIRECT-CURRENT EQUIPMENT

Historical Sketch.—Elevators, even when defined as devices for vertically lifting persons and materials, are by no means a modern invention. It is a matter of record that Archimedes, more than two hundred years before the Christian era, built an elevator. This device, although operated by man power, was not dissimilar in principle to present-day drum-type electric elevators, in that it had a drum on which a hoisting rope was wound. In the latter part of the seventh century a hydraulic-type elevator was introduced into England, but it is only since 1850 that real progress has been made in elevator development. During this period three types of elevators—hydraulic, steam, and electric—in present use have been produced.

A winding-drum type elevator consists of a car attached by one or more ropes to a winding drum to which is connected a counterweight as in Fig. 1. This drum may be electric-motor-driven through a worm and gear, a spur gear, or a combination of both, also in combination with one or more belts. The drum is grooved for the ropes to run in, as in Fig. 2, with counterweight ropes at one end and car ropes at the other. Both sets of ropes run in the same grooves, counterweight ropes unwinding when car ropes wind and vice versa.

Early Types.—An earlier type elevator that still survives operates with straight and crossed belts, Fig. 3. The motor is belted to a lineshaft, which has a wide pulley on it, connected to idler pulleys A and B on the elevator machine by a straight and a crossed belt. The motor is started either by hand and allowed to

run continuously or it is started and stopped automatically from the elevator platform by pulling on a cable. After the motor is running, the elevator is started by pulling on the operating cable in the car, which in turn operates a belt-shifting mechanism through the shipper wheel S. This shifts either the crossed or straight belt to the driving pulley C, which is keyed to the worm-shaft of the machine. Shifting the straight belt to the driving

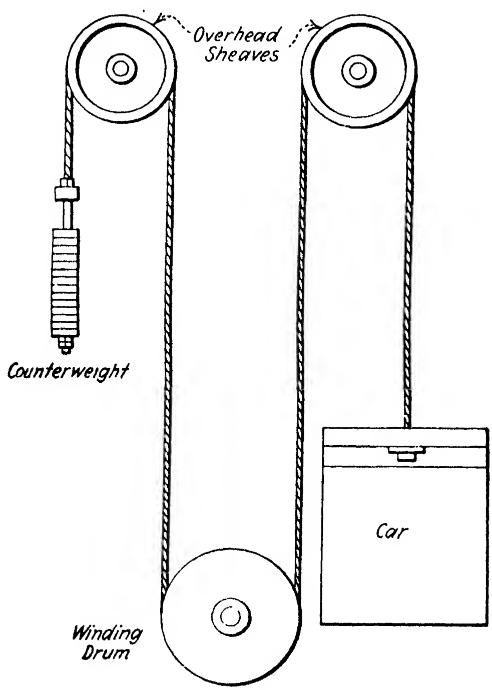


Fig. 1.—Diagram of how car and counterweight are connected to winding drum.

pulley gives one direction of motion to the car, while shifting the crossed belt to pulley C imparts the opposite direction. With this type of machine the motor always runs in the same direction. There have been a great many different arrangements of this type of machine developed, both for operation from the power line-shaft along with the rest of the machines in the building or from an individual motor, as explained in the foregoing, but they all involve the same principle.

The Warsaw Elevator Company's machine, Fig. 3, is arranged for ceiling mounting, while the type, Fig. 4, is intended for floor

mounting. Fig. 4 indicates clearly the belt-shifting mechanism and how it is operated from the shipper wheels S. Rollers O and O' are attached to the shipper-wheel rim and mesh into the forked castings G and G'. Casting G is attached to rod J and G' to J' by set-screws. When the shipper wheel is turned in a clockwise direction, roller O' engages the fork G', moving it to the left and with it rod J' and the belt shifter K', which would move the belt off idler pulley A onto tight pulley C and start the elevator machine in a direction corresponding to the motion of the shipper wheel. When the operating cable is pulled to its central position

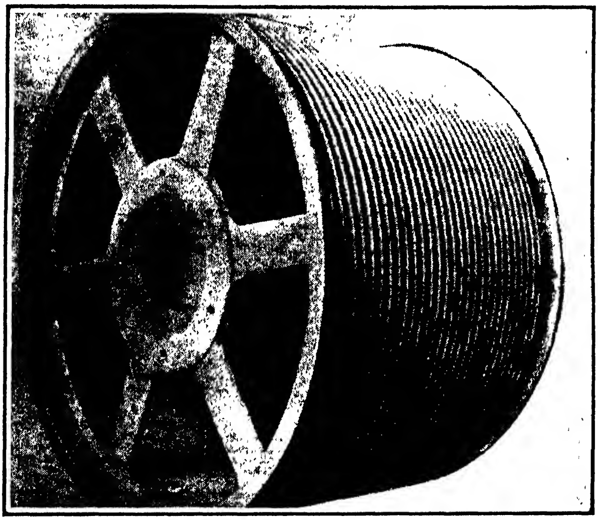


Fig. 2.—Winding drum of elevator machine.

to stop the car, this will bring the shipper wheel to the neutral position, as shown in the figure. Pulling the operating cable so as to turn the shipper wheel in a counterclockwise direction would cause roller O to move fork G tc the right and with it belt shifter K, which will move the belt off idler pulley B onto the tight pulley C and impart opposite direction of motion to the elevator.

Modern Drum Types.—A step in the direction of the modern drum-type elevator was to do away with the lineshaft with its straight and crossed belts and belt the motor directly to the driving pulley on the wormshaft. This involved providing a control for the motor that would not only start and stop it automatically, but also reverse it so as to give the elevator a direction of motion

corresponding to the position to which the operating cable in the car was pulled. The same principles that prevailed in this belted-type elevator are also those in the modern drum-type machine. In the latter type the motor, winding drum, worm and gear are mounted on the same bedplate, with the motor coupled directly to the worm-shaft, as in Fig. 5.

Hand-rope Operated.—Elevator-machine controls may be grouped into two general classes, semi-magnetic and full-magnetic. The semi-magnetically controlled machine is operated by a rope running through the car or by a lever or a handwheel attached to the operating rope. This operating rope is attached to the shipper wheel on the machine which is revolved in a direction corresponding to that in which the hand rope is moved.

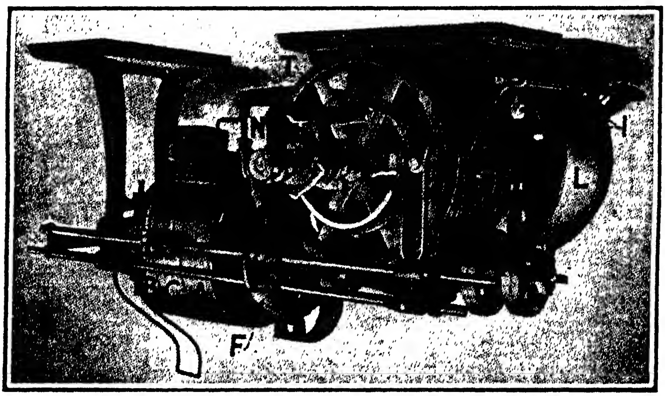


FIG. 3.—Belted-type elevator machine for ceiling mounting.

Attached to the shipper wheel or to the shaft on which the shipper wheel may be mounted, is a connection to the motor controller. According to the direction in which the shipper wheel is moved, the reverse switch on the controller is closed to a position to give the proper direction to the motor. The brake may be either mechanically or electrically operated. With the machines shown in Figs. 3 and 4 the brake F is mechanically operated. A cam H, Fig. 4, mounted on the inside of the shipper wheel, presses against a roller R in the lower end of bell crank D, which is attached to the brake lever at E. As the lower end of the bell crank is moved to the left, the end attached to the brake will be raised and with it the brake lever and weight W. This movement expands the

brake band *F*, releasing the brake wheel, and leaves the machine free to be operated by the motor.

Automatic Stopping at Terminal Landings.—At the top and bottom landings the machine is stopped automatically. Where a mechanically operated brake is used, as in Figs. 3 and 4, and the operating cable runs through the car, automatic stopping at the top and bottom landings may be accomplished in two ways. The first is by placing stop balls on the operating cable at places where they will be hit by the car as it approaches the terminal landings and move the operating mechanism to the central position similar to the way it would be done by the operator. The other method of stopping the car automatically

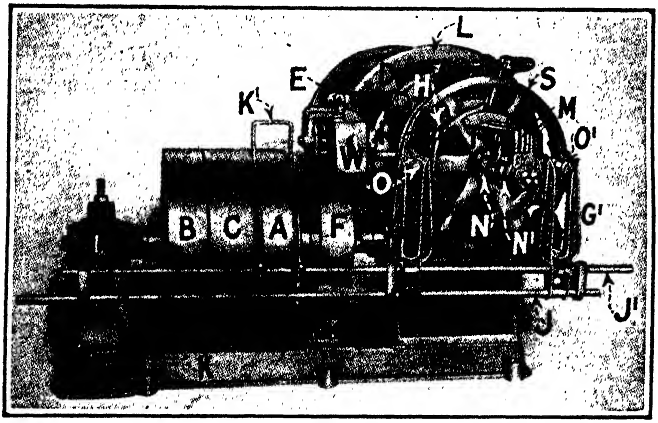


Fig. 4.—Belted-type elevator machine for floor mounting.

is by the drumshaft limits. These limits consist of a traveling nut *T* and two stationary nuts *N* and *N′*, shown on the end of the drumshaft, which is threaded, Figs. 3 and 4. The traveling nut *T* engages the shipper wheel through a casting *M*, which has a tongue on its inner surface that fits into a groove in the end of *T*. On each side of *T* is a lip that, when the car reaches the top or bottom landing, engages a similar lip on the inside of nut *N* or *N′*. With this arrangement the winding drum *L* must turn in an opposite direction to that in which the shipper wheel is turned to start the car.

For example, if the shipper wheel was turned in a clockwise direction the drum would have to turn in a counterclockwise direction for the proper operation of the elevator machine. In

doing this with a right-hand thread on the end of the drumshaft, the traveling nut T would be caused to move toward stationary nut N, which, if properly adjusted, will be engaged by T when the car approaches near the bottom landing. When this occurs, the shipper wheel will be turned in a counterclockwise direction and brought to a neutral position and the elevator stopped by applying the brake. If nut N is adjusted to the proper position, the car will be stopped level with the bottom landing. When the car comes to the top landing, a similar operation takes place when T engages N'. In this case, however, the drum is turning in a clockwise direction and the shipper wheel was turned in a counterclockwise direction to impart this direction of motion to the car. Therefore when T and N' engage, the shipper wheel is turned in a clockwise direction and brought to the neutral position.

Adjusting the Terminal-landing Limits.—Adjustment of the limits is made by first adjusting the stop balls on the operating cable so that the car will stop at the top and bottom floor with full load in the car with the brake properly adjusted. After this has been done, the nuts N and N' on the drumshaft are adjusted so that they will stop the car in practically the same position as the stop balls. The drum-shaft limits should be set slightly behind the stop balls on the operating cable, so that in case these balls slip or the operating cable breaks or becomes fouled in the sheaves, the drumshaft limits will bring the car to rest at the terminal landings.

Where the machine is operated from a handwheel or a lever in the car, the only limits to stop the car at the terminal landings are those on the drumshaft. On machines with an electrically operated brake, as in Fig. 5, a third method of limiting the travel of the car at the terminal landings is made available by opening the line switch and cutting the power out of the machine entirely. This is done by placing a switch at the top and another at the bottom of the hatchway so that they will be opened by the car in case the latter goes by the terminal landings. Opening either one of these switches interrupts the circuit to the holding coil on the main-line switch, which causes it to open and cut the power out of the motor. The opening of this switch also opens the brake-magnet-coil circuit, which allows the brake to be applied and the machine stopped. With a mechanical brake it would be of no use to cut the power out of the motor unless the brake was applied, as the machine would probably keep in motion and control of it might be lost entirely, with serious consequences.

Operation of Brake Mechanisms.—With the Maintenance Company's machine, Fig. 5, the brake is released by the magnet *M* pulling in two cores attached to an extension of the brake shoes at *A*. The brake shoes are fulcrumed on the pins *P* and are applied to the brake wheel by springs *W*. This machine has a shipper wheel *S* on the end of the drum shaft to which the operating cable running to the car is attached as in Figs. 3 and 4. It is also equipped with the drum-shaft limits *T'*, *N* and *N'*. The controller for the motor is attached to the shipper wheel by a chain that runs on the sprocket wheel *J*.

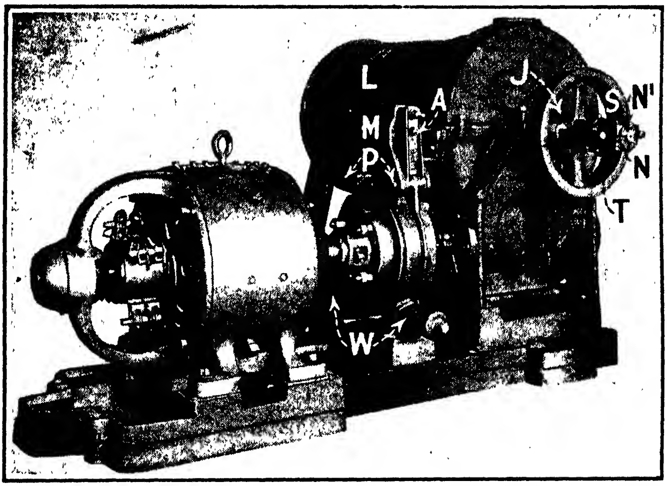


Fig. 5.—Drum-type elevator machine with motor mounted on same bedplate.

Slack-cable Limit Device.—There is one other safety device on the semi-magnetically controlled elevator machine, that is the slack-cable limit. Where the elevator machine is equipped with a mechanical brake, as in Fig. 3, this safety device is mechanical in its operation. The car-hoisting cables come off the winding drum *L* and pass up the hatchway against the small sheaves *I*. While the cables are taut, the framework *Q* is held up in the position shown. Should the cables become slack, due to the car safeties setting on the guide rails or to the car striking the bumpers in the bottom of the hatchway, the framework will be allowed to drop and in doing so will throw in a clutch on the back of the shipper wheel. This clutch connects the drumshaft to the shipper wheel and causes the motion of the drum to bring the shipper

wheel to the off position in the same manner as the drum-shaft limits will at the terminal landings. Where the machine has an electrically operated brake, the slack-cable device generally consists of a bar that runs across the bottom of the drum. This bar is attached to a switch, known as the slack-cable switch, in series with the holding coil on the main-line magnet switch. Should the cables become slack for any reason, they will strike the bar and open the slack-cable switch, which in turn opens the main-line switch and causes the elevator machine to be stopped.

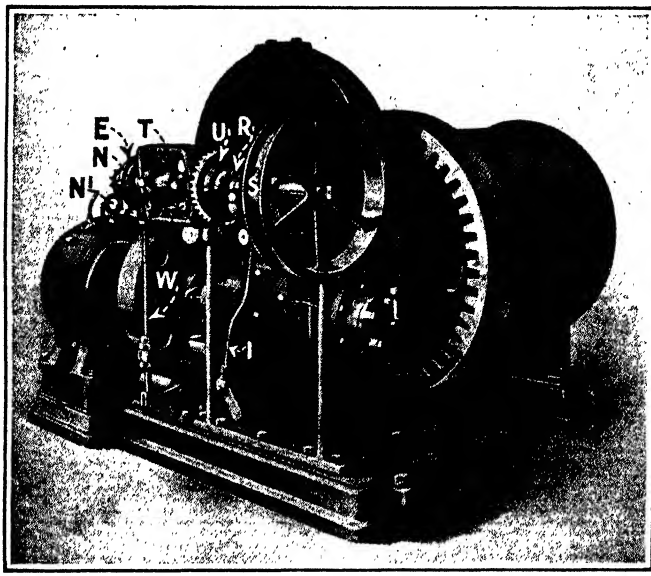


FIG. 6.—Internal-geared drum-type elevator machine.

Methods of Driving the Winding Drum.—In all three machines Figs. 3 to 5, the winding drum L is driven by a worm and gear, the drum being keyed or bolted directly to the gear-wheel and shaft. With the machine Fig. 6, built by the Warsaw Elevator Company, the gearshaft has a spur gear keyed to it which in turn meshes into an annular gear on the winding drum, thus giving two reductions in speed from that of the motor. This arrangement allows a slow speed on the drum with a high-speed motor.

In the machine Fig. 6 the shipper wheel S and limits are not mounted directly on an extension of the worm-gear shaft, but on a short shaft mounted at right angles to it. These two shafts

are connected by beveled gears *U*. On the end of the operating shaft is an eccentric *E* which releases and applies the brake through rod *W*. Part of the slack-cable device is under the drum and arranged so that, should the cables become slack, clutch *R* is thrown into mesh with the shipper wheel through rod *I* and causes the machine to stop.

Types of Elevator Machines.—Electric elevators have been developed in a great many different forms, but in general they can be grouped in two classes, drum-type and traction-type. On the drum-type, one end of the hoisting cable is attached to the car and the other end to the winding drum on which the cables are wound to hoist the car. On the traction type, the ends of the cables connect to the car and pass over a traction sheave to the counterweights where the other ends are attached. This traction sheave is either mounted directly on the motor shaft or is driven through a worm and gear, and the friction between the cables and sheaves is depended upon to transmit the driving force from the motor to the car and counterweights.

Types of Control.—These two groups can be subdivided according to their types of control into a number of classes. One is semi-magnetic control, in which the machine is controlled from some mechanical device in the car such as a hand rope, wheel or lever, as previously explained. Another very large class is the full-magnetic control, in which the machine is controlled from a switch in the car. Another class that is coming into quite extensive use is the full-automatic controlled or push-button type, in which no operator is employed. In the highest development of this machine, to call the elevator to the floor the passenger pushes the landing button as for the operator-controlled type. However, instead of giving a signal to the operator in the car, when the landing button is pushed, the elevator automatically comes to the floor and stops. After it stops the car gate and landing door open automatically and remain open a definite time to allow the passenger to get on the car, when they again close automatically. The passenger pushes a button in the car of the same number as the floor to which it is desired to go. This puts the car in motion, and it goes to this floor and stops, after which the car gate and landing door open automatically, remaining open a definite time to allow the passenger to get off the car. After the passenger has had time to get off the car, the door and gate close automatically and the car is again available for use by someone else. On the earlier

types of this machine the landing doors and car gate were opened and closed by the passenger.

In another class, a combination of hand and full-automatic control is used, and this is known as dual control. During that part of the day when the traffic is heaviest, an operator is on the car and controls it from a car switch. When the traffic is light, the control is thrown over onto the full automatic, in which case the passenger controls the operation much the same as for the full-automatic machine.

One of the latest developments in elevators is that known as "signal-control." In this type the machine is full-automatic controlled in every sense of the word, although it has an operator in the car. In distributing the passengers to the different floors the operator simply pushes buttons in the car corresponding to the floors that the passengers call. After the buttons are pushed the car goes to these floors and stops automatically. When a passenger on a landing pushes a button to signal the operator the first car coming in the direction signaled will stop at this floor.

Micro-drive machines are another development that is coming into quite extensive use. In this type the main machine brings the car within a short distance of the floor at which it is desired to stop. When the operator brings the car switch to the off position, the main machine is switched out of service and a small slow-speed, or what is known as a leveling machine, switches into action automatically and brings the car level with the floor. This machine will also maintain the car level with the floor during loading and unloading and compensate for the stretch in the cables. It is now general practice to do the automatic leveling with the main machine.

Classification of Control Equipment.—For machines operated on direct current, the control may be divided into rheostatic constant voltage, where a resistance is used to give reduced voltage at starting; multi-voltage, where means are provided to apply the starting voltage in definite steps such as 25, 50, 75 and 100 per cent as the machine comes up to speed; and variable-voltage, where the voltage at the motor terminals is gradually increased and decreased during the starting and stopping period by controlling the voltage of the generator supplying the motor. In alternating current the control can be divided into two general classes—those for single-speed motors and those employed with two-speed motors.

Basement Installations of Drum-type Machines.—Drum-type machines are in general built for two classes of installations—basement and overhead. In Fig. 7 is shown a complete installation of an Otis Elevator Company's basement-type machine for passenger service. This machine is representative of the better classes of drum-type machines in use today with full-magnetic control from an operating switch in the car. Two sets of cables run from the drum *D*—car and counterweight. The car cables run from the back of the drum up the hatchway over a sheave *S* and to the car crosshead *C*. The counterweight cables come from the front of the drum and go under the vibrating sheave *V*, up the hatchway over the overhead sheaves *S′* and down to the drum counterweights *W*. A third set of cables runs from the car to the car counterweights *W′*.

Weight of Counterweights.—The two sets of counterweights are usually made equal in weight to the weight of the car plus 40 per cent of its rated load. For example, if the car weighed 1,000 lb. and its rated load was 2,000 lb., the counterweights would weigh 1,000 lb. plus 40 per cent of 2,000, or 1,800 lb. This weight of counterweight has been found most efficient for general installations and gives the minimum loading on the machine for average conditions.

With the counterweight equal to the weight of the car plus 40 per cent of its rated load, the motor for driving the machine need be only 40 to 50 per cent of the size it would have to be if no counterweights were used, besides making it possible to stop the car and its load with a much smaller brake and also reducing the strain on the elevator equipment in general.

The cables are arranged on the drum so that as one set winds on the other set unwinds; this allows both sets to make the use of the same grooves. To allow the cables to pass to the drum counterweights, the car counterweights are slotted in the back and the cables are covered with steel tubes to prevent abrasion. In all cases the car counterweight cables are placed above the drum counterweights. This is done so that in case the drum counterweight cables were to break, these counterweights cannot fall on the car counterweights and overbalance the car. In such a case the counterweights would fall and raise the car and might cause a serious wreck.

Compensating Chains and Cables.—In Fig. 8 a chain *H* can be seen running from the bottom of the car to the bottom of the

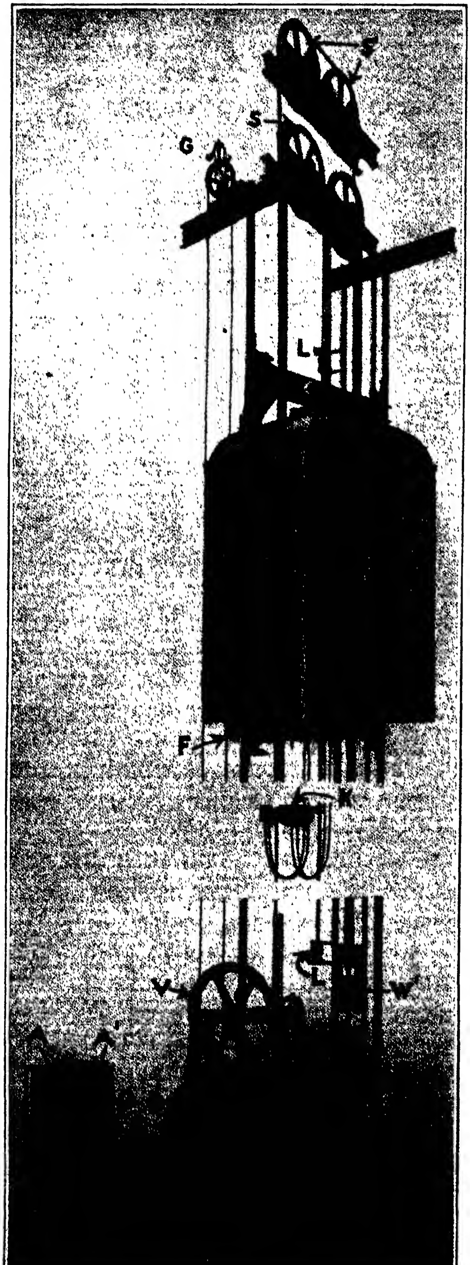


Fig. 7.—Typical basement installation of drum-type elevator machine.

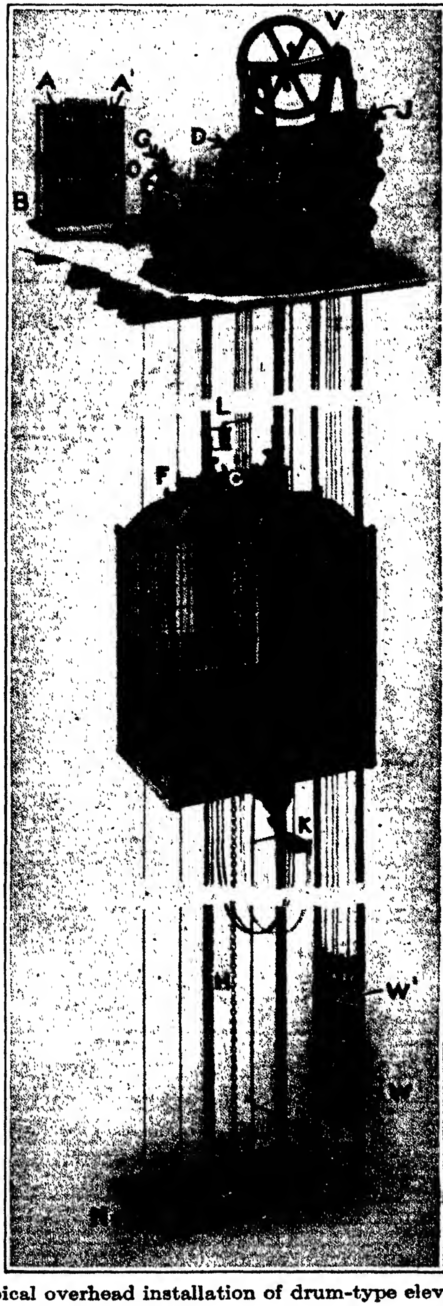


Fig. 8.—Typical overhead installation of drum-type elevator machine.

counterweights. This chain is used to compensate for the weight of the cables being shifted to the counterweights when the car is at the top landing and shifted to the car when at the bottom landing. In the figure the car is shown near the top landing and the counterweights are at the bottom. In this case the weight of four cables for the full length of the hatchway has been shifted to the counterweights and taken off the weight of the car. If the cables weigh 400 lb., then 400 lb. has been taken off the car and put on the counterweights, or there has been a change in weight of 800 lb. between the car and the counterweight in traveling from the bottom to the top landing. In going from the bottom to the top landing, the weight of the compensating chain has been transferred from the counterweights to the car. Therefore, if the chain weighs the same as the cables, as much weight has been added to the car as was removed and the counterweighting remains the same for any position of the car. This compensating chain, or cables as sometimes used, is not necessary except on medium- and high-lift machines. Where chains are used, to prevent them from being noisy, a hemp rope is laced through the links.

Overhead Installations of Drum-type Machines.—On the drum-type machine installed overhead, Fig. 8, the arrangement of the cables is similar to that for the drum-type machine installed in the basement, the chief difference being that the overhead-sheave construction has been eliminated. On the overhead machine the drum counterweight cables come up the front of drum *D* and go down the back to the counterweights, where the car cables come up the back of the drum and down the front to the car. The car-counterweight cables come from the car up over vibrating sheave *V* and down to the counterweights. This is the arrangement where the diameter of the drum equals one-half the width of the hoistway. Where the hoistway is wider than two times the diameter of the drum, deflecting sheaves are used for the counterweight cables to divert them down the hoistway.

The arrangement of the governor *G* and cable can be clearly seen in the two figures. This cable runs over a sheave on the governor and around a weighted sheave *N*, in the hoistway pit, Fig. 8. In this particular installation the two ends of the cable are attached to a fitting *F* at the bottom of the car, Fig. 7, and at the top, Fig. 8. This fitting is held in a clip so that the governor cable moves with the car. The governor is equipped

with flyballs similar to a steam-engine governor, which, when the car runs above a predetermined speed, are thrown out and operate a dog that grips the cable and pulls it out of the clip at *F* on the car. Pulling the governor cable free from the car will set the

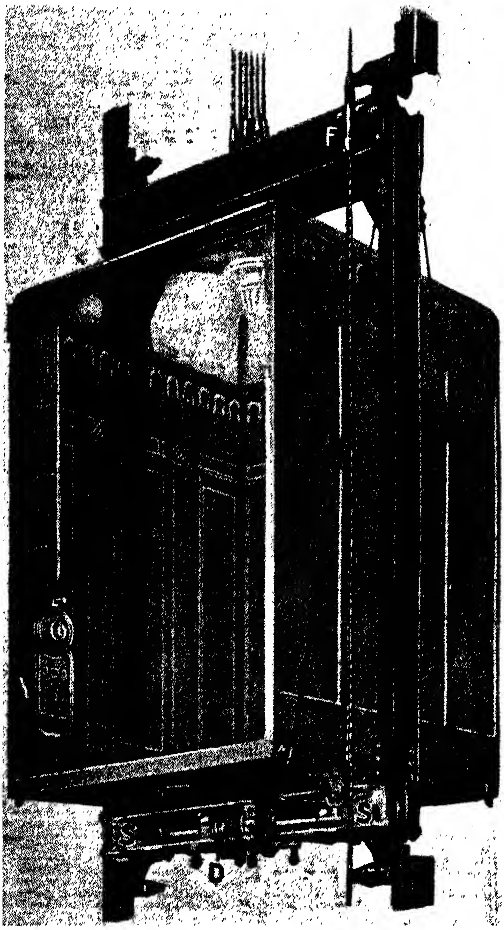


FIG. 9.—Elevator car showing location of safeties at *S*.

safeties under the car to prevent it from falling in case it gets out of control or the hoisting cables break.

One arrangement for setting the safeties is shown in Fig. 9. One end of a second rope is attached to a drum *D* located in the

safety plank under the car. This rope is wound up on the drum, and the other end is attached to the governor cable at F. When the governor cable is pulled free from the car, the cable on the drum is pulled out and causes the drum to turn. The revolving of this drum operates right- and left-hand screws which force wedges between the ends of the safeties S in such a way as to cause them to grip the guide rails gradually and stop the car.

When the safeties are set by action of the governor, the power may be cut off from the motor in two ways on a drum-type machine. In one, when the governor operates, it opens a switch which interrupts the circuit to the holding coil of the main-line or potential switch on the controller, which causes this switch to open and stops the machine. The other method is to allow the car cables to become slack after the safeties set, which will cause the slack-cable switch to open the main-line switch.

Operation of the Controller.—The controller used on the machines, Figs. 7 and 8, is representative of those used on medium-speed drum-type machines, in that it has a main-line or potential switch B; two direction switches A and A', one which closes for up motion of the car and the other for down motion, and an accelerating magnet switch O for cutting out the starting resistance. When the operating switch in the car is thrown to the up position, one of the direction switches closes and completes the circuit through the motor's armature in one direction, and when the operating switch is thrown to the opposite position, the other direction switch closes and completes an opposite circuit through the motor's armature, thus reversing its direction and that of the car. These direction switches are so interlocked that one must be open when the other is closed. When the direction switches close, they also close the circuit to the brake magnet coil E, which releases the brake and leaves the elevator machine free to be operated by the motor.

Limit Switches.—To connect the operating switch in the car to the controller, a flexible cable runs from the car to a junction box K halfway up the hoistway. This gives a flexible connection that allows the car to travel the full length of the hoistway. From this junction box the wires generally lead to the controller in metal conduit.

On the machines shown in Figs. 7 and 8, there are two sets of limits. One of these is at J and consists of a number of contactors opened and closed by cams operated from a traveling nut on the

end of the drum shaft. The second set is the hatchway limit switches located at *L* near the top and bottom landings. One set of contactors located at *J* are the first to open, as the car approaches the terminal landings, and interrupt the circuit to the direction switch, which should cause this switch to be opened and the car brought to rest by applying the brake. If for any reason the direction switch did not open and the car continued in motion, a second set of contacts would open shortly after the first and open the coil circuit to the potential switch *B* and cause it to open. This would cut the power out of the motor and apply the brake. Should the drum-shaft limits be out of adjustment and allow the car to go by the terminal landing, then a cam on the car would strike one of the hatchway-limit switches *L* and open it. Opening the hatchway-limit opens the circuit to the coil of the potential switch with the same effect as if it were opened from the drum-shaft limits.

Slack-cable and Governor Switches.—In addition to the limit switches mentioned in the foregoing, there is the slack-cable switch and in some cases a switch on the governor as previously stated. The slack-cable switch is under the drum and is in series with the holding coil on the potential switch. When the cables become slack on the drum, owing to the safeties setting on the car or other causes, the slack-cable switch is opened which in turn opens the potential switch and stops the motor. Where a governor switch is used, in case of overspeed that causes the governor to operate and set the safeties, the governor switch is opened and the motor stopped by the opening of the potential switch.

Thrust Bearings.—Another important part of an elevator is the thrust bearings. Owing to the unbalanced weight of the car or counterweights the worm gear exerts a thrust on the worm that must be taken care of by thrust bearings. One common arrangement is shown in Fig. 10, where ball-type thrust bearings are shown at *T*. In other cases roller thrust bearings are used, and again in others, bronze and steel disks are employed. On some types of elevators both thrust bearings are included in the rear wormshaft bearing, as shown at *A* in the sectional view of a worm and gear Fig. 313. This latter arrangement places both thrust bearings where they can be inspected and adjusted without taking out the wormshaft as has to be done on many types of machine in use.

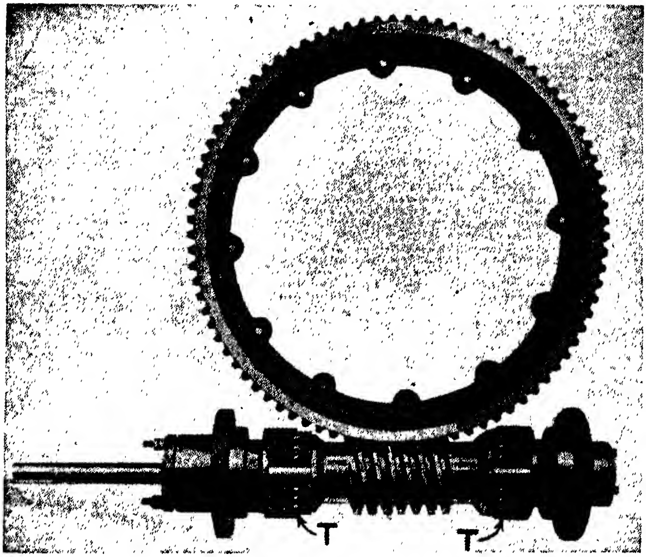


FIG. 10.—Worm and gear with ball thrust bearings at *T*.

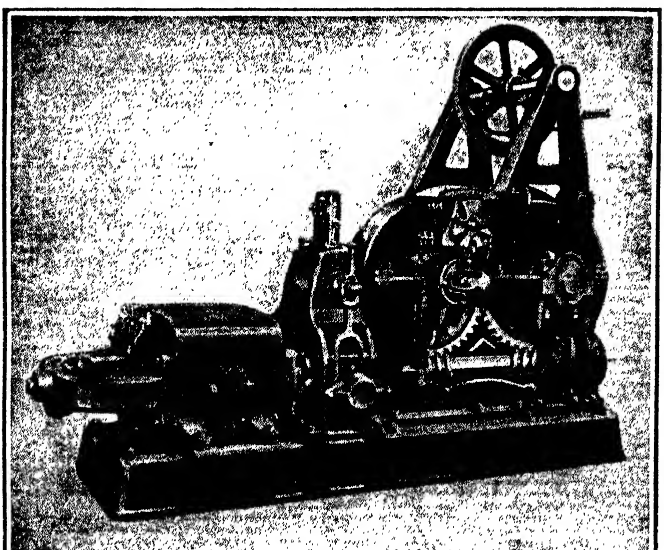


FIG. 11.—Tandem-geared elevator machine requires no thrust bearings on wormshaft.

Instead of using a single worm-gear drive, as in Figs. 7 and 8, a tandem worm and gear is employed, as in Fig. 11. The rear gear is mounted on the drum shaft and meshes with the front wheel, the wormwheels being driven by tandem worms. This gearing automatically absorbs the thrust, and no thrust bearings are required.

Different makes of elevator machines will have different arrangement and construction of mechanical details, but all drum-type machines are essentially the same as those described in the foregoing.

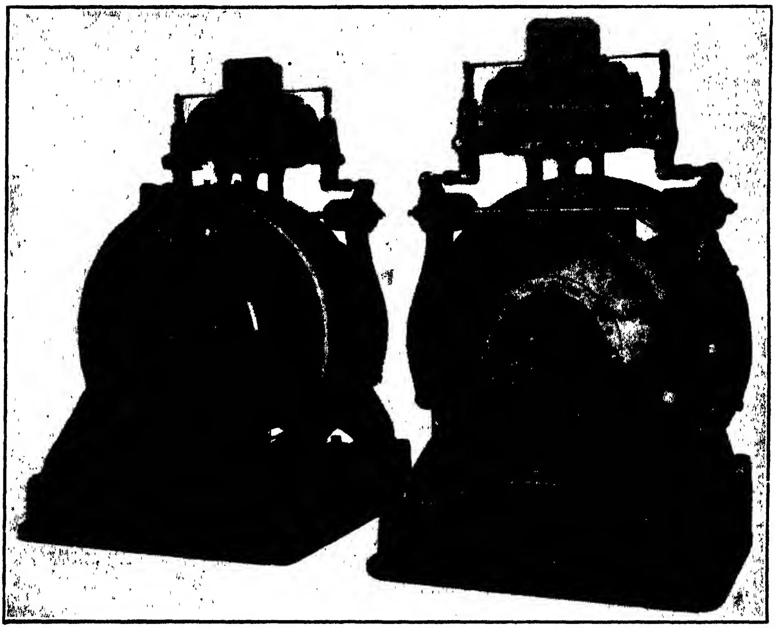


Fig. 12.—Direct-traction elevator machine.

Traction-type Machines.—Although the principle of the traction drive is old, its successful commercial application to an elevator has taken place within the last twenty years. With the drum-type machine, limitations as to the length and diameter of the winding drum restrict the use of this machine to lifts of about 150 ft. or less. The advent of the modern skyscraper building made it imperative to develop a type of elevator that would be suitable to high-rises, and the traction-type came into commercial

use. This machine has proved so successful that it is rapidly superseding all other types.

The highest development of traction elevators is found in the high-speed direct-traction, sometimes called gearless-traction, machine. A machine of this type, built by the A. B. See Electric Elevator Co., is shown in Fig. 12 and consists of a slow-speed (about 65-r.p.m.) direct-current motor having the traction sheave and brake wheel mounted directly on the motor shaft. This

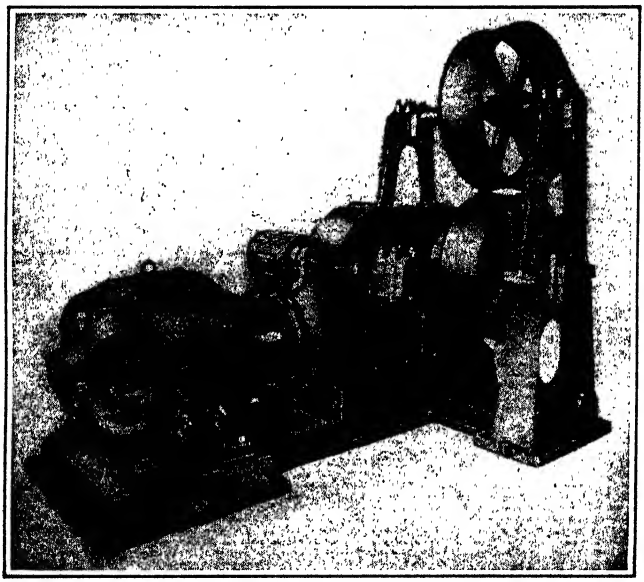


FIG. 13.—Tandem-geared traction-elevator machine.

equipment is used for car speeds up to 1,400 ft. per min. To permit using a high-speed motor, geared-traction machines are used. One type of this equipment built by the Westinghouse Elevator Co. is shown in Fig. 13. This machine consists of a high-speed motor and a tandem worm and gear, one of the gear shafts being extended on which is mounted the traction sheave. Figures 313 and 314 show sectional views through the worm and gear and the traction sheave of a Turnbull Elevator Co.'s machine for car speeds up to 500 ft. per min. The worm is a multiple-thread type, which in this case has seven threads.

Other Types of Elevator Machines.—In addition to the foregoing arrangements a single worm and gear may be used; single worm and gear with internal spur gearing; single-worm and gear with external spur gearing; single herringbone gearing; and car leveling single worm and gearing used in conjunction with either a direct-traction or a geared-traction machine on a micro-drive installation. Any of the machines may be roped single wrap or double wrap and for a 1-to-1 or a 2-to-1 speed ratio, as will be subsequently explained.

In the traction type of elevator machine, instead of winding on a drum as for the drum-type installation, the cables run over a traction sheave and unwind off as fast as they wind on. On the drum-type machine the grooving on the drum forms a helix like the thread on a screw and generally starts at one end and runs to the other. The grooves on a traction sheave form closed circles about the sheave, the number of grooves depending on the number of cables and method of roping.

On some large freight elevators, ranging up to 30,000-lb. capacity or more, two machines geared to the same drum have been used. The controllers are so connected that the two machines operate as a unit from the car switch. In other installations, two independent machines have been roped to the same car and their controllers so connected that the two machines operate as a unit. Both drum-type and traction-type machines have been applied in these combinations.

Traction Machines with 1-to-1 Roping.—In Fig. 14 is shown a complete installation of a full-wrap direct-traction machine, roped for a speed ratio of 1 to 1, as built by the Otis Elevator Co. From this figure it will be seen that the cables pass from the car crosshead at C, over the traction sheave S, around the secondary sheave S', then over the traction sheave S and to the counterweight crosshead at W. There are usually 6 cables used on these machines, and as the cables pass over the traction sheave twice, this sheave will have 12 grooves. On account of the cables making two half wraps around the traction sheave, this type of equipment is known as a full-wrap machine. A machine similar to that in Fig. 14 is shown in Fig. 16, from which the way that the cables pass around the sheaves may be more clearly seen.

The speed of the car depends on the size of the traction sheave and the speed of the motor. The traction sheave must be large enough in diameter so that the bending stresses in the cables will

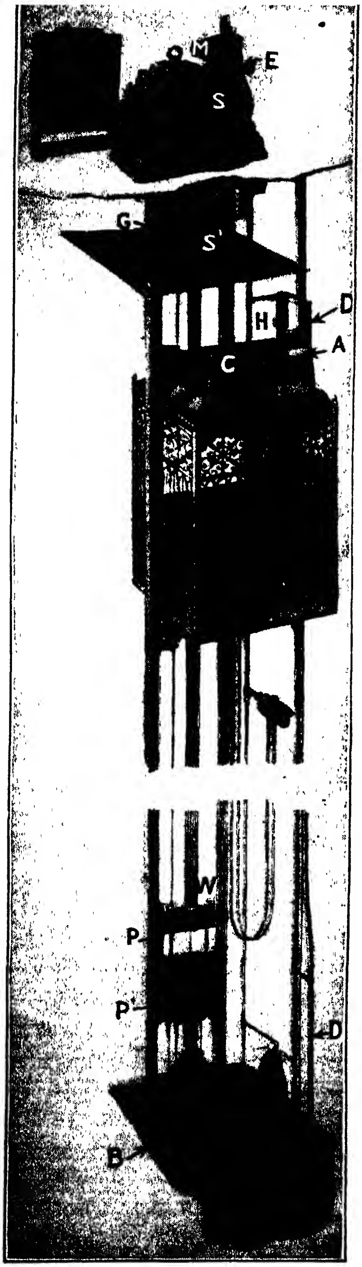


FIG. 14.—Traction-elevator installation with 1-to-1 roping.

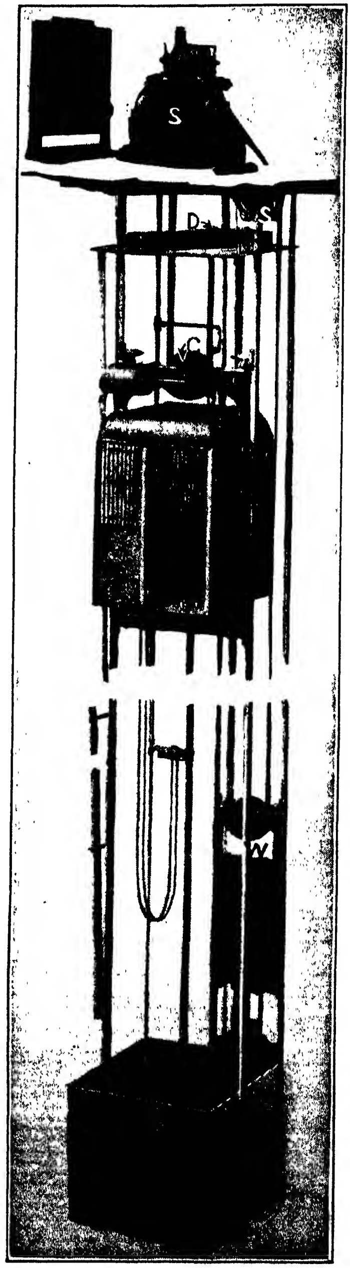


FIG. 15.—Traction-elevator installation with 2-to-1 roping.

not be excessive and give a reasonable cable life. The minimum diameter of traction sheave is about 28 in., or about 40 cable diameters, where the maximum diameter is limited by the car speed required and it must not exceed the span between the car and counterweight centers. A sheave 36 in. in diameter and a car speed of 600 ft. per min. will require a motor speed of only $600 \div \frac{36 \times 3.1416}{12} = 63.6$ r.p.m. From this it is seen that the speed of a motor on a direct-traction machine is necessarily very slow. On account of these limitations the direct-traction 1-to-1 machine is limited to a car speed of about 400 to 1,400 ft. per min. In Fig. 14 the car speed is the same as the cable speed, and for this reason the machine has what is called a 1-to-1 roping.

Traction Machines with 2-to-1 Roping.—In some installations a roping is used that will give a ratio of rope speed to car speed of 2 to 1 as in Fig. 15. In such installations the motor can be operated at double the speed for the same car speed obtained with a 1-to-1 roping. Or, conversely, the car speed with a 2-to-1 roping would be one-half that for a 1-to-1 machine using the same motor speed in both installations. The 2-to-1 type of installation is generally limited to where car speeds of 350 to 500 ft. per min. are required.

In the geared-type traction machine a high-speed motor is used and the desired car speed is obtained by using the proper gear reduction. Motor speeds for this type of installation vary from about 400 to 1,000 r.p.m., depending upon the size of the motor and type of installation. The geared traction is used with either a 1-to-1 or 2-to-1 roping and is applied to car speeds ranging from about 50 to 700 feet per minute.

Certain installations require the application of a gearless-traction machine to a comparatively slow-speed installation, since the amount of power that can be transmitted by a worm and gear is limited. There is practically no limit to the amount of power that can be applied to a gearless-traction machine, except the traction between the cables and traction sheave and the space requirements for the machine. At certain of the New York subway stations gearless-traction elevators that have a lifting capacity of 11,000 lb. at 350 ft. per min. are used. These machines have 2-to-1 roping and are the equivalent of a machine for a capacity of 5,500 lb. at 700 ft. per min. with 1-to-1 roping.

Safety Features of Traction Machines.—One of the features of a traction elevator machine is that in case either the car or the

counterweights bottom, the traction is lost between the cables and traction sheave and the car or the counterweights, as the case may be, will not be pulled into the overhead work as might happen with a drum-type machine. There is only one exception to this and that is in the case of a very high building, the weight of the cables hanging down the shaft may be great enough to maintain sufficient traction to lift the car or counterweights. To prevent this, some of the high-rise installations are equipped with retard-

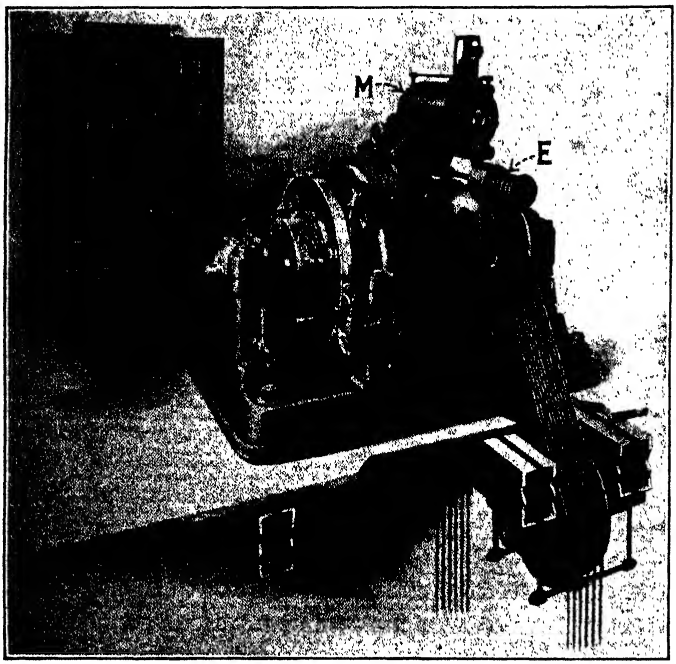


Fig. 16.—Gearless-traction machine with cables on traction and idler sheaves.

ing devices which come into action after a certain amount of over-run has taken place and prevent further travel of the car or counterweights, so that the cables must slip on the traction sheave.

Compensating Cables on Traction Machines.—In Fig. 14, in addition to the set of cables running from the top of the car over the traction sheave to the counterweights, a second set of cables runs from the bottom of the car around a sheave *T* in the bottom of the pit up to the lower end of the counterweights. These are the compensating cables and compensate for the transferring of

the hoisting-cables' weight from the car to the counterweights or vice versa. For example, in the figure the car is near the top landing and the counterweights at the bottom. In this position most of the hoisting-cables' weight has been shifted to the counterweights; however, the weight of the compensating cables has been transferred to the car. Since the two sets of cables weigh the same, there has been no change in the relation between the weight of car and counterweights. The sheave *T* and its housing on the compensating cables are free to move vertically on guides in the pit, and the weight of the sheave and housing is depended upon to keep a suitable tension in the compensating cables.

There are certain safety features provided by the compensating sheave in that if either the car or counterweights bottom, further motion lifts the sheave and tends to prevent the car or counterweight from being pulled into the overhead work as might be the case in very high rises. A switch is generally provided on the compensating sheaves so that in case it lifts above a certain point the switch opens and this in turn opens the main-line switch on the controller and cuts the power out of the machine entirely.

Fig. 17.—Combination oil-spring buffer, which is placed at bottom of hatchway to bring car to rest in case of overtravel at bottom landing.

Oil Spring Buffers Used.—Connected to the bottom of the counterweights is an oil spring buffer. A similar type buffer *O* is in the bottom of the pit to arrest the motion of the car should it go below the bottom landing. This buffer is so constructed that it brings the loaded car to rest from full speed without discomfort to the passengers. A sectional view of the buffer is shown in Fig. 17. As the buffer is compressed, oil is forced from the inner

to the outer cylinder through holes indicated at *H*. When the piston is unloaded, the spring returns to its normal position.

Safeties Used on Both Car and Counterweights.—On the high-speed traction machine safeties are used on both the car and counterweights. In Fig. 14 one side of the governor cable passes over two small sheaves at *P*, then down around the drum on the counterweight safeties and out over two other pulleys *P′*. From the counterweights the governor cable passes around the tension sheaves *B* in the pit and then to the car, where it is deflected over

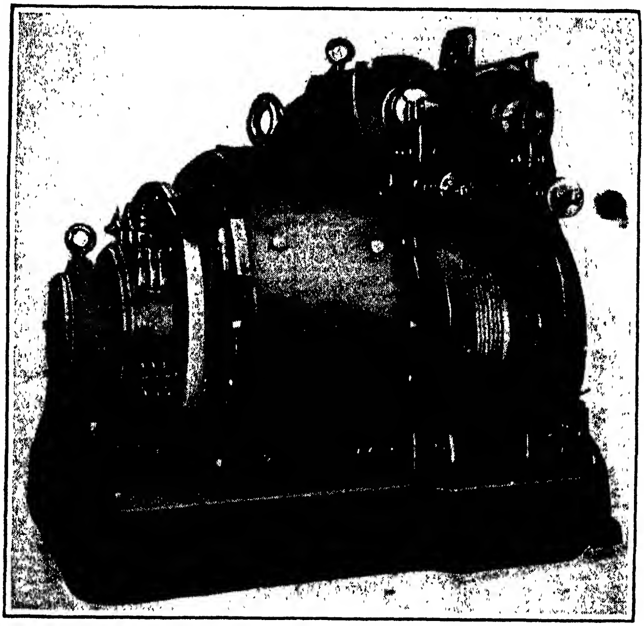


Fig. 18.—Gearless-traction machine with two brakes.

small idler sheaves under the car and makes two turns around the drum on the car safeties. From the car-safety drum the cable passes over an idler sheave to a releasing carrier at the top of the car and back over the governor sheave *G* to the counterweights. Should the hoisting cables part, the downward motion of the car and counterweights causes the governor cable to rotate the safety drums and apply the clamping jaws to the guide rails and bring both car and counterweights to rest.

In one type the safeties are held off the guide rails by an electromagnet under the car. In case of overspeed the governor opens

a switch which interrupts the circuit to the electromagnet, which in turn allows the safeties to be applied by heavy springs and the car gradually brought to rest. In many installations a hand wheel is provided in the car, so that the operator can apply the safeties by hand in case the car should for any reason get out of control.

Operation of the Brake.—The brake wheel and traction sheave are, on some direct-traction machines, keyed on the armature shaft, and in other cases bolted to the armature spiders. There being no reduction gear between the traction sheave and the brake, the latter must be strong enough to hold the maximum difference in weight between the car fully loaded and the counterweights. For this reason the brake is much larger than on a gear-type machine. The brake shoes are released by the magnet *M* and applied by heavy springs *E*, Figs. 14 and 16. Where direct-traction machines are to be used for safe lifting or other heavy purposes, they are sometimes equipped with two brakes, Fig. 18.

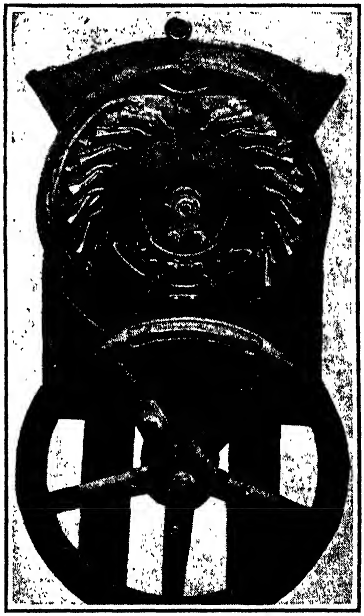


Fig. 19.—Car switch with cover removed for high-speed traction-elevator machine. The wheel is for operating the car safeties in case of emergency.

Car-switch Control.—The control of the machine is from a switch in the car, as for a drum-type machine. However, where the machine is used for high speeds, it is possible to obtain as high as seven different speeds from the car switch. This is necessary not only for smooth acceleration, but also to allow the operator to make landing stops with ease. A car switch with the cover removed for a traction elevator machine is shown in Fig. 19. The hand wheel just below the switch is for applying the safeties in case the car gets out of control.

On account of cable creepage on the traction sheave, machine limits to stop the car at the terminal landings cannot be used as for the drum-type machine. Two general schemes of limit stops

are used. With one arrangement a series of switches are located in the hatchway at the terminal landings and a cam is attached to the car, which opens these switches. The first switch to open slows the car down and the last brings it to rest.

In Fig. 14 the limit switches are mounted on top of the car at *A* and a cam *D* is mounted at both the top and bottom landings. As the car approaches the landing, the cam opens the limit switches and gradually brings the car to rest. Final limit switches *H* are mounted in the hatchway, so that if the car passes the landings it will open one of these switches, which in turn will interrupt the circuit to the potential switch on the controller and cut the power out of the machine.

With the exception of the method of roping up the machine to the car, the 2-to-1 direct-traction elevator is practically the same as the 1-to-1 machine. A complete 2-to-1 installation is shown in Fig. 15. One end of the hoisting cables is dead-ended to the overhead beams at *D*. From *D* the cables pass around a sheave *C* in the car-sling crosshead and back up over the traction sheave *S*. After passing around the traction sheaves *S* and the idler sheave *S′* one-and one-half times, the cables go to the counterweights and around under sheave *W*, then back to a dead end *D′* in the overhead beams. With this arrangement the car speed is only one-half that for 1-to-1 roping, with the same motor speed and same size traction sheave in both cases.

Instead of the idler sheave *S′*, Fig. 15, being directly under the traction sheave, as in Fig. 14, it is offset toward the counterweight side of the hatchway (also see Fig. 16). This is done where the distance from the center of the car to the center of the counterweights is greater than the diameter of the traction sheave. Where this condition exists, the idler sheave is used also as a deflector to lead the cables vertically down to the counterweights.

V-grooved Type Traction Machines.—Another type of traction machine is that known as the V-grooved type, sometimes called pinch-groove or half-wrap machines. In such machines the grooves in the traction sheave are V-shaped and the cables pass directly from the car over this sheave to the counterweights. No idler sheave is used and the traction between the cables and sheave is obtained largely by the wedging effect of the cables in the grooves. This type of machine is rapidly coming into use. The cables make one half-wrap on the traction sheave, thus the name half-wrap type machine. Other types of traction machines

have been developed and are in use, but those described give a good general idea of this class of equipment.

In the single-wrap machine the maximum contact arc between the cables and sheave cannot exceed 180 deg. and is less than this for equipments using a deflecting sheave. In modern single-wrap machines different types of grooves are used, but they all are shaped so that the cables cannot bottom in the grooves, which allows a pinching action between the sides of the grooves and cables, as indicated in Fig. 21. One of the difficulties with this arrangement has been to have all the cables travel at the same

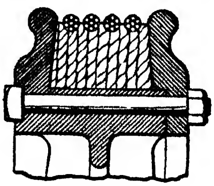


Fig. 20.

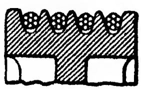


Fig. 21.

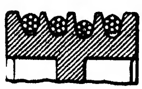


Fig. 22.

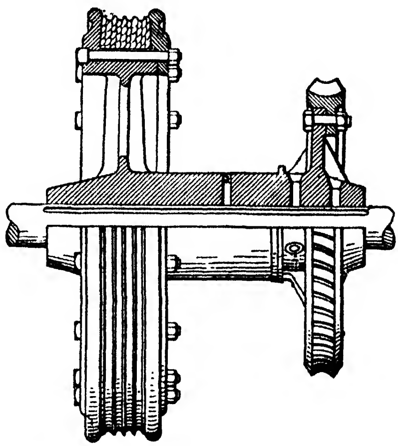


Fig. 23.

Figs. 20 to 23.—Sections through single-wrap traction-elevator machine sheaves. Figs. 20 and 23—Show construction of hemp-fiber packed sheave. Fig. 21—Section of V-grooved sheave with all cables and grooves the same size. Fig. 22—Condition that can develop on a V-grooved sheave when the cables or grooves wear unevenly.

speed. To obtain this condition it is necessary that all the grooves and cables be alike. If one cable or groove wears more than another, a condition similar to Fig. 22 will exist on the sheave and cause the cables to travel at different speeds, therefore they will have to slip in the grooves to compensate the difference. When a 30-in. "V"-groove sheave has worn so that one or more cables be $\frac{1}{16}$ in. lower than any of the others, the creep will mount to about 10 in. for a 200-ft. lift. Obviously, under such conditions the wear on the cables will be severe.

Traction Elevators with Fiber Packed Sheaves.—To increase the friction between the cables and traction sheave of single-wrap machines without the pinching action of the V-groove type,

and at the same time reduce the wear on the cables, a hemp-fiber-packed sheave has been developed by F. R. Neenan of New York City. As shown in Figs. 20 and 23, the sheave's face is built up of short pieces of hemp fiber rope set radially and held between two flanges, and it is known as a fiber-packed sheave. The fiber is held under a pressure that makes it a solid mass. After the sheave has been assembled, it is put into a machine and the grooves, which are semicircular in shape, are rolled in. The idea is to get the conditions in a rope drive where a hemp rope is run on iron or steel sheaves. In the hemp-packed sheave the arrangement is reversed—an iron or steel rope runs on a hemp-fiber

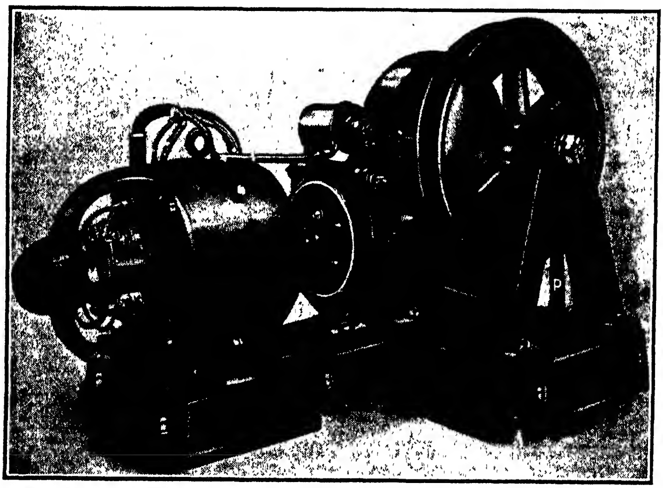


FIG. 24.—Traction-elevator machine with hemp-fiber packed sheave.

sheave. Where, with a steel sheave and ropes it is necessary to use six cables to obtain sufficient traction, with the hemp-packed sheave a lesser number of cables may be used on the same lift. An elevator machine of the worm-gear single-wrap traction type with a fiber packed sheave is shown in Fig. 24.

Stopping the Car Level with the Floors.—Accuracy of landing and the maintenance of the car-platform level with the landing floor during loading and unloading are two important factors in elevator service. In passenger-elevator service, as the speed of the elevator machine is increased, landing the car accurately becomes more difficult. With the usual types of control greater dependence must be placed on the operator's skill to make the

landing without undue slowing down of the service, either by slowing down the car too early before stopping, or on account of the operator's failure to make the landing accurately, having to inch the car either up or down.

Accurate landing is also a factor in eliminating hazards due to passengers' tripping. When the car is stopped level with the floor, passengers will move on and off the car in less time than when they must step up or down at the bidding of the operator. Therefore accurate leveling of the car's platform with the landing floors will tend to improve the elevator service as well as decrease

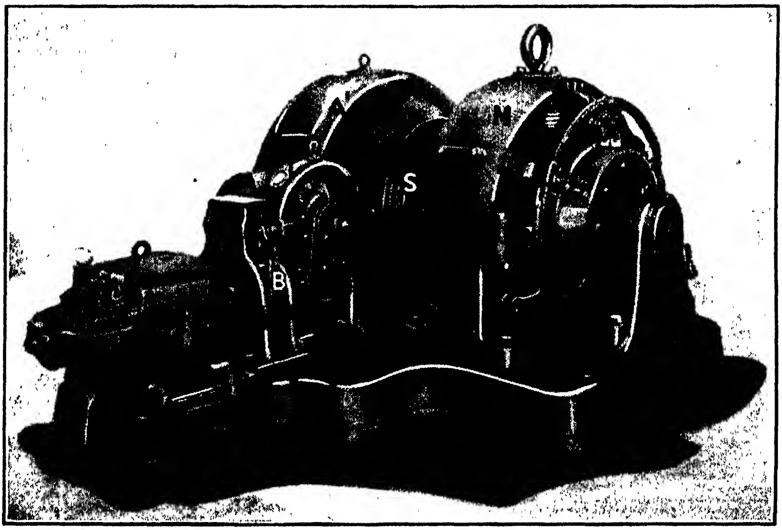


Fig. 25.—Micro drive applied to a direct-traction elevator machine.

the time required to make a round trip. This is particularly true where landing-door interlocks are used and the car must be stopped nearly level with the floor before the door can be opened.

If accurate landings can be assured, not only is it possible to render better and more service with a given number of elevators, but when elevator service is being considered for a new building, it may be possible to reduce the number of elevators installed. This would result in a reduction in the cost of the elevator installation and increase the renting space in the building, which is an even larger factor.

In freight-elevator service stopping of the car level with the landing floors and maintaining this level greatly facilitates the

movement of freight on and off the car. It also reduces the wear on freight-handling equipment such as trucks, as well as the damage to merchandise when being loaded on and off the elevator. Maintaining the car level with the landing floor will result in greater safety to employees handling the freight. One of the difficulties in keeping a freight elevator level with the floor is to take care of the stretch in the cables with a change in the load.

When heavily loaded trucks are being put on the car, if the latter's platform is maintained level with the landing floor, the elevator equipment will be relieved of the severe strains of the load dropping two or three inches or a greater distance on the car floor. Preventing these heavy shocks to the equipment will assist materially in reducing the wear, which will not only keep down maintenance costs, but result in better service from elevator equipment.

To start and accelerate the elevator consumes a considerable percentage of the power required to operate the machine. If accurate landings can be made without inching the machine, the power consumption will be kept at a minimum. The power that can be saved by eliminating inching of the elevator will vary with the type of control, being a minimum with an adjustable voltage control and a maximum with rheostatic control. Prevention of inching also reduces the wear on the controller and other parts of the equipment.

Micro-drive Traction Machines.—A number of developments in elevator design have been made with the object in view of making the leveling of the car to a large degree automatic or independent of the operator. One of these developments is what is known as the micro-drive machine, Fig. 25, built by the Otis Elevator Co. A number of different forms of this machine have been brought out, but that shown in the figure is one of the latest.

So far as the main motor *M* and traction sheave *S* are concerned, they are the same as for the standard direct-traction machine. In addition to the main machine a second, known as the micro-machine, consisting of a motor *M′*, brake *B* and worm gear *G*, is attached to the main machine through suitable gearing. In the figure a small spur gear at *A*, is mounted on an extension of the micro-machine's worm-gear shaft and meshes into a large gear in the case *A′*. The brake shoes are supported on the inside of this gear wheel, and the brake wheel is keyed to the traction-sheave shaft. The brake wheel and brake are so arranged that when the

brake is released the main machine is free to move as in the usual design. When the brake is applied, the micro-machine is connected to the main machine. In other words, the brake and brake wheel on the main machine act as a clutch between this machine and the micro-machine.

The micro machine is of small capacity and is only capable of operating the car at a slow speed such as is suited for making accurate landings. For medium-speed machines the micro-machine gives a car speed of 30 to 60 ft. per min., where on high-speed installations the micro-machine gives a car speed of 45 to 90 ft. per min. However, this does not have a slow-down effect on the elevator's operation since the micro zone does not come into

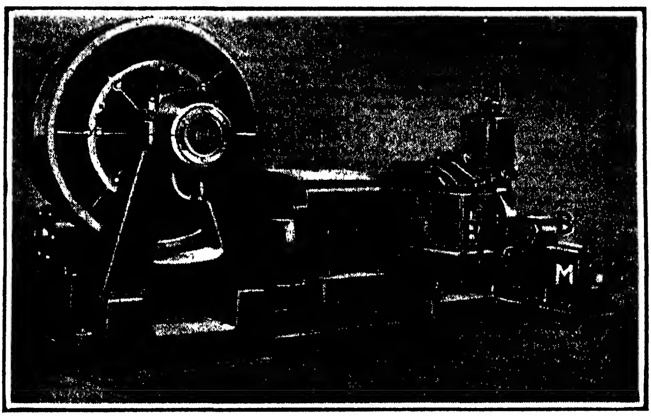


FIG. 26.—Micro drive on a geared-traction machine.

effect until the car is within about 10 in. above or below the floor, for car speeds up to 400 ft. per min. For car speeds of over 400 ft. per min. the micro zone is reached when the car comes within 16 to 18 in. of the floor.

Controller of Micro-drive Machines.—With the micro-leveling machine there are two controllers, one to operate the main machine from the car switch, as in the usual type of medium- and high-speed traction elevator machine. The other controller is for the micro-machine and is brought into operation automatically as the car approaches the floor at which a stop is to be made by a switch mounted on top of the car and cams in the hatchway. This switch has two sets of contacts, one for up motion and the other for down. There are two sets of cams at each landing, one that

operates the micro-machine and brings the car up level with the floor and the other for bringing the car down level with the floor

Figure 29 shows a complete installation of a micro-drive traction machine. A comparison of this figure with Figs. 14 and 15 will show that with the exception of the micro-machine being added to the main machine, there is very little difference between this equipment and the standard traction installation.

In Fig. 29 a full-wrap roping is used; that is, the cables pass from the car crosshead over the traction sheave around the secondary sheave S and back over the traction sheave and to the counterweights. The micro-drive can be applied equally well to the half-wrap machine, where the cables pass directly from the

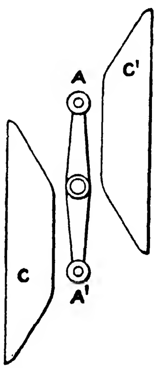


Fig. 27.—Position of micro switch arm A when car is in normal operation.

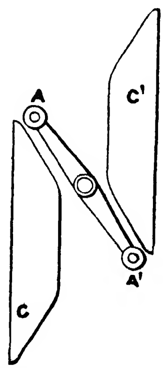


Fig. 28.—Position of micro switch arm A when car is stopped level with landing.

car over the traction sheave to the counterweights. It can also be applied to traction machines with two-to-one roping or to the geared type of machine, Fig. 26, or to any application that requires that the elevator car floor be maintained accurately level with the landing floor. In Fig. 26, B is the brake on the main machine and acts as a clutch between the main machine and the micro; the latter's motor is shown at M and the brake at B'.

Two Kinds of Installations.—There are two kinds of installations, one where it is required that the car make accurate landings at the top and bottom floors, such as on hoists, and the other where intermediate stops are made, as is the case in regular passenger- or freight-elevator service. In the latter a magnet M is mounted on top of the car, Fig. 29, to prevent the micro control from being brought into service as long as the car switch is held

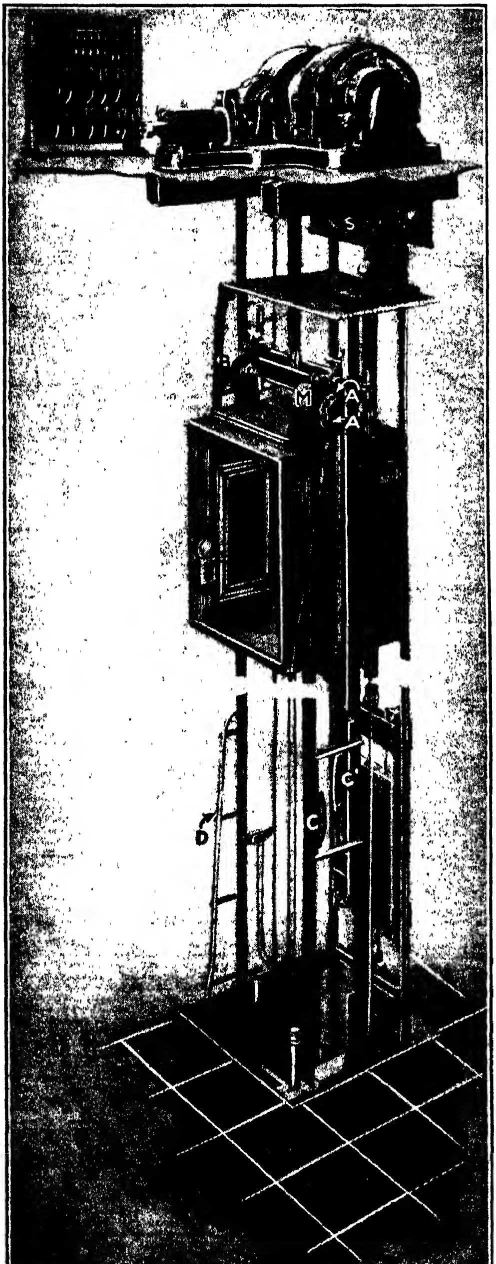


Fig. 29.—Complete installation of direct-traction machine with micro drive.

in the on position. This magnet holds the arms A and A' on the leveling switch from engaging cams C and C' in the hatchway. With the car in the down motion, on approaching the bottom landing an arm on switch B, on top of the car, is engaged by cam D, which operates the switch and slows the car down. When within about 12 or 16 in. of the landing the main machine is cut out automatically and arm A' on the leveling switch engages cam C' and cuts the micro-machine into operation, which brings the car down level with the floor. Should the car for any reason go below the floor, cam C would operate the leveling machine and bring the car up level with the floor. The same operation takes place at the top landing. For clearness in the figure the leveling cams at the top floor have not been shown.

At the intermediate landings the operator must, on approaching a floor where a stop is to be made, bring the car under control, and when within a few feet of the landing bring the car switch to center, in much the same way as for the standard machine. Then when the car comes within 16 or 18 in. of the floor, the micro-machine is switched in automatically and the car brought level with the landing and stopped.

Figure 27 shows the position that arms A and A' on the micro-leveling machine are held in when the car is in normal operation, and Fig. 28 shows the position of the arms with the car stopped level with the floor. If for any reason the car drops below the floor, arm A will strike the upper end of cam C, which will close the switch on the micro-machine for the up motion and the car is brought up level with the floor. On the other hand, should the car go a short distance above the floor, such as would be the case when a heavy load is taken off, arm A' will strike the lower end of cam C' and the micro-machine is put in motion and brings the car down level with the floor. With modern control the micro-leveling switch is on the selector, Chapter XVI.

Although in Fig. 29, the controller for the main machine only is shown, a controller is also provided for the leveling machine. On the main machine the control may be of the multi-voltage type, as in the figure, or of the variable-voltage or rheostatic types, where the micro-machine control is a rheostatic type.

The accuracy with which the micro-machine will maintain the car level with the floor will depend upon conditions. For passenger service where the micro-machine speed should be comparatively high, a ½-in. variation in the levels of the car at landing

floors would be allowed. In freight service, where much slower car speeds are used, the variation would be not over ¼ in., while in general the car would be maintained absolutely level with the landing floor.

Another advantage of the micro-drive machine is the ease with which it may be adapted to lifting heavy loads, such as safes. Where the standard type of traction machine is used for this purpose, it is necessary to equip the machine with an additional brake, as in Fig. 18. With the geared-type machine it is necessary to have the machine arranged for back gearing as in Fig. 30,

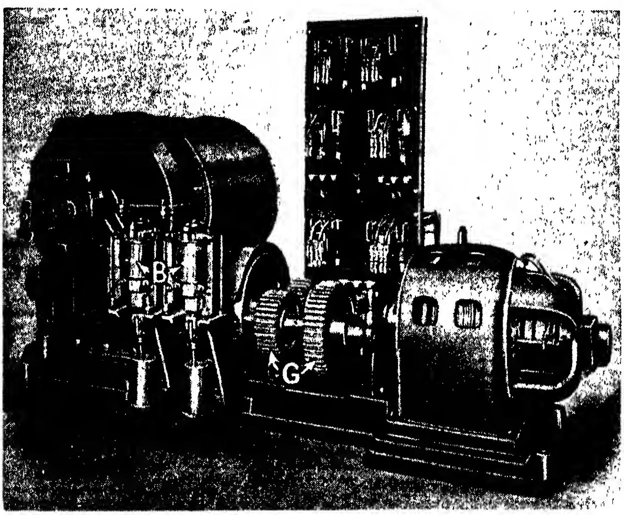


FIG. 30.—Heavy-duty drum-type machine with back gearing and two brakes.

which shows a Warsaw Elevator Company's drum-type machine arranged for back gearing at *G* and equipped with two brakes *B*. In the micro-drive machine all that is necessary is to tighten the brake springs on the main machine so that the brake will have sufficient friction to act as a clutch in transmitting the power from the micro-machine, which is used to lift the load.

Electron-tube Leveling.—Another method for automatically leveling an elevator car at the landings, developed by the General Electric Company, uses pliotrons. This system is applied with variable-voltage control and leveling is done with the main machine.

A pliotron composed of a filament, a grid and a plate, as indicated in Fig. 31, will oscillate if coils are arranged in the grid and the plate circuits in proximity to each other so that their fields couple and if the grid coil is suitably tuned with a capacitor across it. The plate coil, the grid coil and grid-coil capacitor are in the figure. The frequency at which the circuit oscillates is determined by the frequency of the tuned grid circuit. In standard General Electric elevator-leveling units this frequency is about 200 kilocycles.

Inasmuch as the coupling between grid and plate coil is essential for oscillation, breaking this coupling will stop the

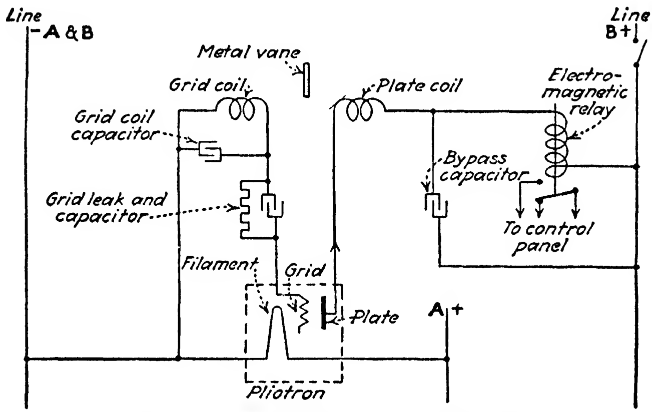


FIG. 31.—Diagram of a pliotron connection.

oscillation. One of the car leveling units is shown in Fig. 32. *P* is the pliotron and the way the grid and plate coils are mounted back of the unit is indicated at *C*. How these coils are mounted is more clearly shown in Fig. 33. Inserting a metal vane in the space between the two coils prevents coupling of their fields and stops the oscillation of the circuits.

In an oscillating circuit of the kind described a considerable change in plate current occurs when the circuit goes in or out of oscillation. The plate current will be low when the circuit is oscillating and high when oscillation ceases. If an electromagnetic relay is connected in series with the plate circuit and the relay coil by-passed with a capacitor, as in Fig. 31, the difference in plate current through the relay coil will be further increased between the oscillating and non-oscillating states,

because the highly inductive relay coil will not pass radio frequencies, but the capacitor in multiple with this coil will.

In a non-oscillating condition the capacitor will pass no current and the relay will freely pass the direct current. The operation then will be, with the vane between the grid and plate coils, the relay will be closed by the direct current; with the vane absent and the circuit free to oscillate, the relay will be open. The

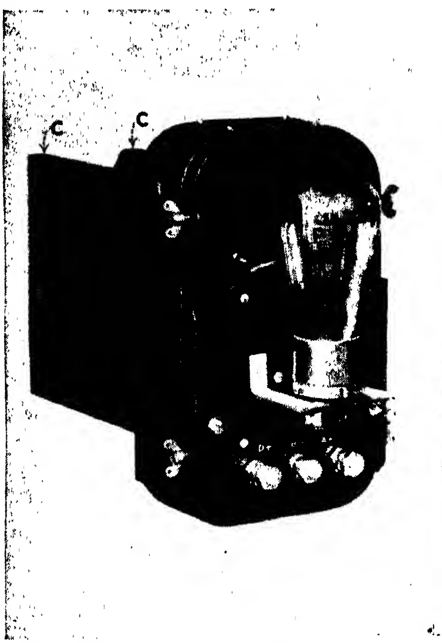


Fig. 32.—The coils mounted in *C* are in plate and grid circuits.

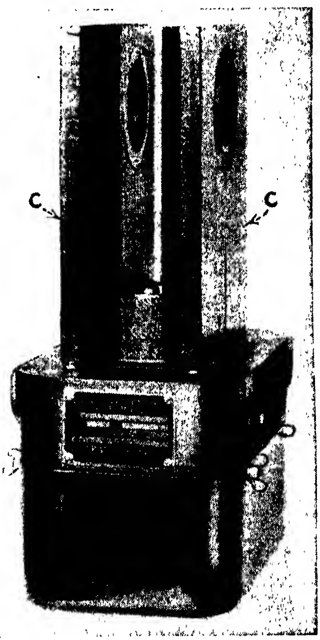


Fig. 33.—Pliotron unit with the cover removed.

pliotron unit shown in Figs. 32 and 33 has approximately one-inch air space between the grid and plate coils, and $\frac{1}{16}$ in. radial movement of the edge of the vane between the coils is sufficient to pick up or drop out the relay. This pick-up and drop-out distance may be reduced if requirements demand.

Figure 34 shows a group of pliotron units mounted on the crosshead of an elevator car as used in a preregistering signal-control elevator system. On the photograph, *R* is one of the car guide rails, *S* one of the car-guide shoes, *H* the car crosshead, *T* pliotron tubes, *U* one of the pliotron units attached to the car crosshead and *V* is one of the metal vanes, clamped to the guide

rails, which act on the pliotron circuit to level the car at the landings.

From the foregoing it is seen with this leveling system no mechanical connection of any kind is made in the hoistway with the control equipment. Slowing down and leveling the car at the floors is accomplished by metal vanes, properly located in the hoistway, passing through the space between the grid and the

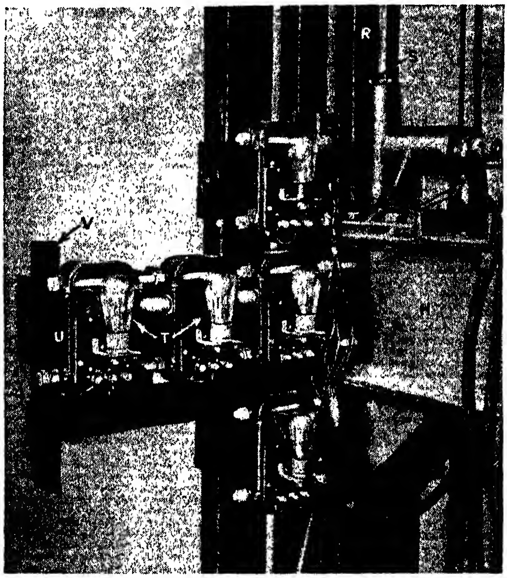


Fig. 34.—Pliotron leveling units mounted on the car's crosshead. *H* is the crosshead; *R*, the guide rail; *S*, the guide shoe; *T*, pliotron tubes; *U*, one of the pliotron units attached to the car's crosshead; and *V*, is one of the metal vanes clamped to the guide rails, that acts on the pliotron circuit to level the car at the landings.

plate coils on the pliotron units, which in turn cause relays to function to carry out the slowing-down and stopping operations.

The leveling operation is smooth. Transition from the first to subsequent approach speeds is imperceptible, and the final leveling-in to the floors is so gradual that the passengers are barely conscious of the change in speed until the car comes near to rest and a landing is made. The lever acts directly on the main traction motor and involves no auxiliary driving mechanism.

Automatic or self-leveling elevators, as previously described, operate on the principle that inaccurate stops are corrected for

by automatically moving the car to the floor level from the point at which it first stops. Should the car stop short of the floor, the car is automatically caused to move in the same direction to the floor level. Should the car travel beyond the floor, the leveling switch will reverse it and cause the car to move back to the floor level.

Automatic-landing Equipment.—Methods of automatically stopping elevator cars level with the landings have been devel-

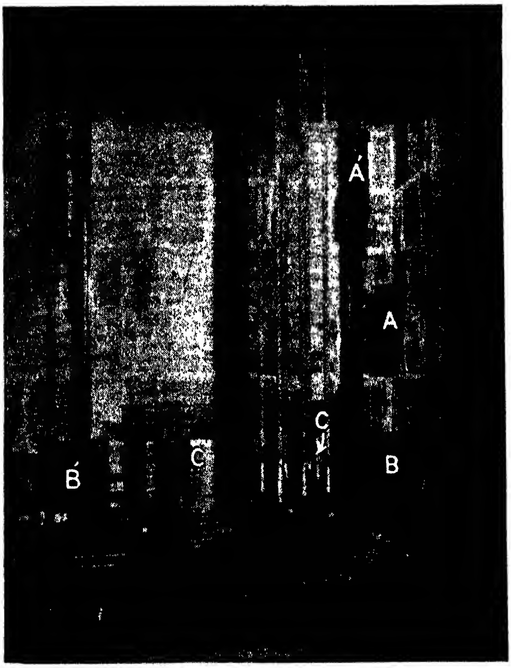


Fig. 35.—View of top of the car and the rear of the hoistway.

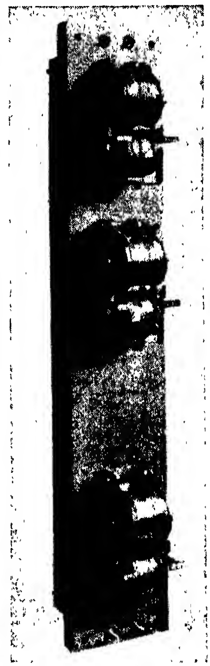


Fig. 36.—Stopping inductor switch.

oped. With these systems if for any reason the car fails to stop level with the landing the error will not be corrected automatically. To make the stops accurately it is necessary that stopping begin exactly at the right distance from each floor. Automatic landing was made possible by the development of variable-voltage control, which allows very accurate control of the car's speed. The highest-speed elevators in the world, operating at 1,400 ft. per min., in the Rockefeller Center main building, New York City, are automatic-landing type.

Automatic Inductor-type Control.—A control for automatic-landing elevators, known as the automatic-inductor type has been developed by the Westinghouse Electric Elevator Company. With the inductor control all operations of automatically slowing down the car and stopping it accurately at landings are accomplished without any mechanical contact between control parts on the car and stationary parts in the hoistway.

In the hoistway, mounted on the counterweight guide rails, are what are known as inductor plates, such as shown at A and A',

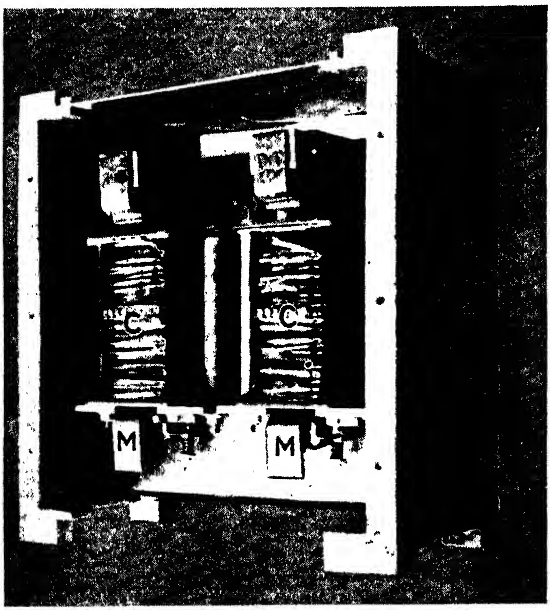


Fig. 37.—Inductor switch for first and second slow-downs.

Fig. 35. On top of the car are slow-down inductor switches B and stopping inductor switches C. These switches are totally inclosed in metal cases to protect them from dust and dirt. On the side of the cases next to the inductor plates non-magnetic material is used.

The inductor switch consists of a coil and magnet and a normally closed contact, Fig. 37. As shown in the figure, there are two inductor switches, one the first slow-down and the other the second slow-down. With car-switch control, when the operator centers the car switch, coils C become energized and magnets M excited. When a magnet comes in front of its

inductor plate, it is attracted and opens its contacts. Opening the contacts interrupts the circuit to the slow-down relay on the elevator-motor control board and decreases the car speed.

In Fig. 35 it will be seen that inductor plate A is out of line with A'. This allows No. 1 slow-down to function first, and as the car continues in motion the second slow-down inductor switch is operated by plates A'. Final stopping of the car is done by the stopping inductor, which contains three switches. This inductor switch is shown in Fig. 36 with the cover removed. The final slow-down and stopping are accomplished by an inductor plate, not shown in Fig. 35, which causes stopping inductor switch C to function as the car approaches the floor. The inductor plates in the hoistway are adjusted to give a minimum stopping distance and obtain a smooth and accurate stop.

Preregister Control.—Elevators of the automatic-landing, or the automatic-leveling, car-switch type, traveling at high speed, require a more complete signal system than do ordinary car-switch-controlled machines. With the latter, waiting passengers on landings signal the car operator by pressing a button that indicates on an annunciator the floor number and direction in which the passenger wishes to go. On another system a flash-light in the car signals the operator, when approaching a floor, where passengers are waiting to go in the direction of car travel.

These systems function satisfactorily where cars have open-grille gates and travel at moderate speeds. As car speed increases it becomes more difficult for the operator to read floor numbers and to judge stopping distances. These difficulties may cause a large number of false stops to be made or the car may be prematurely slowed down before making a stop, causing a reduction in service rendered by the elevator. Where cars with solid doors are used they must be stopped at the floors automatically, as the operator cannot see the landings. On car-switch-controlled cars in this service the signal system must be so designed that it will indicate to the operator when to center the car switch, after which the car stops level with the floor automatically.

A preregistering signal system gives the operator a signal to center the car switch as the car enters a stopping zone at full speed. Auxiliary signals are given to the operator when the car is at the first of two successive floors at which stops are to be made. The system may also be used to slow down the elevator automatically from the registered stop signals if desired.

A preregistering signal system that accomplishes these requirements has been developed by the Elevator Supplies Company. With this system there are the usual up- and down-signal buttons at the landings. There are signal lanterns over each hoistway door to indicate to waiting passengers which cars are approaching the floors and direction in which they are going. This arrange-

Fig. 38.

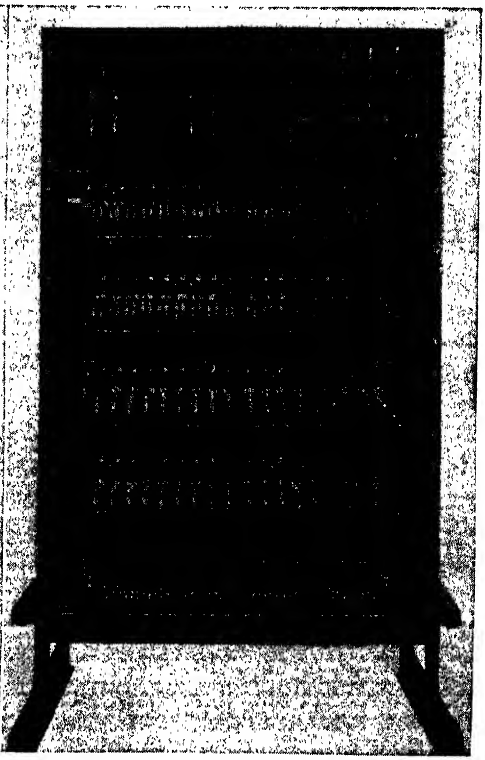


Fig. 39.

Fig. 38.—The bank of push buttons above the car switch is for the pre-register signal system.

Fig. 39.—Master floor-relay control panel on which there are two mercury-contact relays for each intermediate floor and one for each terminal landing.

ment is the same as is frequently used with elevators having the conventional type of car-switch control.

In each car above the car switch is a panel on which there is a button for each floor, as shown in Fig. 38. The operator presses buttons corresponding to the floors called by passengers when entering the car. When a button is pressed it is held in the

closed position, indicating to the operator where stops are to be made. The closed button also completes a circuit to a selector in the machine room. As the car travels up or down the hoistway a contact is made on the selector that flashes a signal light for the operator to center the car switch. This light is in the center at the top of the panel Fig. 38.

With this particular type of elevator control the signal light is an added precaution, since the operator does not have to depend on it to know when the car switch is to be centered. Slow-down is initiated by the registered signal, after which the operator centers the car switch. If the operator did not notice the car slowing down the signal light's flashing would show that the car switch should be centered to make a stop.

Door-control Contacts.—The car- and hoistway-door control contacts are on the car switch. When the operator moves the switch to a start position, the doors close and the car starts and accelerates to full speed. With one type of control, when the car enters a stopping zone, as established by a button being pressed in the car or at a landing, the car slows down, after which the operator centers the car switch. The car then stops level with the floor for which the signal was given, and the car and landing doors open automatically. When registered stop signals occur consecutively, requiring stops at adjacent floors, or at two-floor intervals, the car does not attain full-rated speed, but automatically slows down, and the warning signal is given the operator in a manner similar to that when making a stop from full speed.

When signals are registered on the car operator's panel, the buttons, being mechanically locked type, remain in closed position until the car approaches a terminal landing, when they are released automatically. Car-signal panels contain one button for each floor served, the same button being used for either direction of travel. If it is desired to reverse the car between terminal landings, the push button can be manually reset by button *R*. Should the operator be unable to take on additional waiting passengers, floor calls may be bypassed by switch *B*. Placing this switch in bypass position will transfer registered passenger signals to the next approaching car, but will not affect registered stop signals on the car operator's panel.

Automatic-dispatching System.—At top of the panel the two small lights are for an automatic dispatching system. One light

flashes when it is time for the operator to leave the first floor and the other flashes when the car should leave the top landing. The automatic dispatching system not only relieves the dispatcher of signalling the operators when to leave the first floor but it also insures that they will be signalled at the proper time at both terminal landings. This assists the operators to run closer to schedule than can be done by manual dispatching.

The small switches just above and below the car switch are part of the elevator control system and for the lights and fan in the car and are not a part of the signal system.

Preregister Control with Two Signal Lights.—On another system of elevator control operating with preregister signals two signal lights are used, usually of different color, to distinguish between high-speed two-floor and one-floor stop signals. With this control, when a car running at high speed enters the zone of a registered stop signal a contact is made on the signal selector. This gives a visible red and an audible signal to the operator to return the car-switch handle to the off position, after which the car enters the stopping zone, is slowed down and stops automatically at the floor.

When stop signals occur two floors in advance of the floor at which a stop is made the operator's red signal will flash. To make a stop the car switch is centered after the car has traveled several feet. When registered calls occur consecutively, requiring stopping at adjacent floors, the operator receives a visible green signal when the car stops, indicating that a stop is to be made at the next floor. To make an adjacent floor stop the operator centers the car switch immediately after starting.

Selector Commutator.—In the control room there are selector commutators, relay panels and other equipment essential to the signal and control system. The commutators for the floor stops, the floor lanterns, night annunciator, car-position indicator and other operations are assembled in a single unit, Fig. 40. Vertical commutators of the straight-line double-screw type are used, except when the car speed is slow and the segment requirements are such that a standard friction-reversing commutator can be used. The commutator is driven from the elevator's secondary sheave by a chain and sprockets. Stop nuts are assembled and locked on the screws and a friction stud is used on the drive shaft, so that commutator-brush position will be corrected at each end of travel if necessary. Small pressed-steel

"H" sections form supports for the segments, which are inserted between and insulated from them. This arrangement of the "H" bars allows any desired assembly of the segments. By loosening the holding nut on a segment it may be readily adjusted to any position.

The brushes that pass over the segments during travel are of the roller-contact type and are adjustable both vertically and

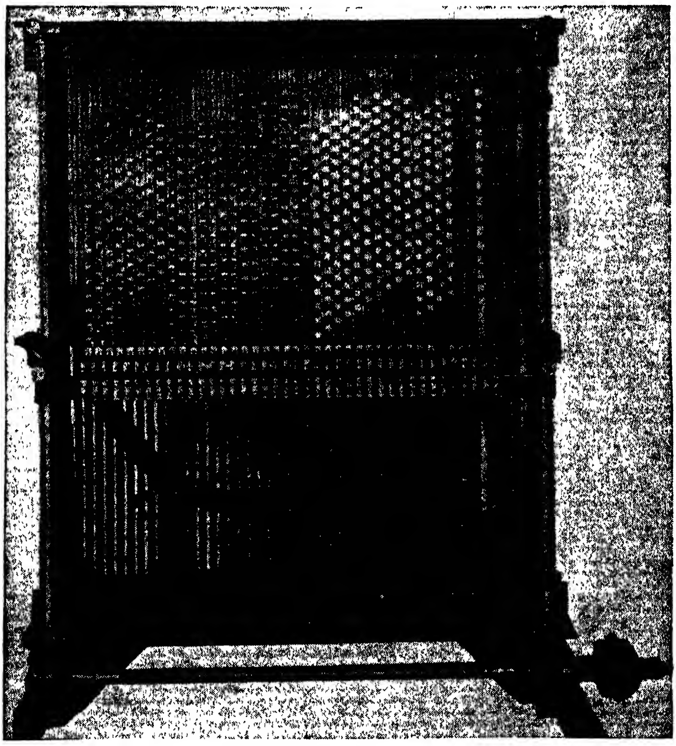


FIG. 40.—Front of the commutator assembly for the floor stops, floor lanterns, night annunciator, car-position indicator and other operations.

horizontally. Connections are taken from the brushes by flexible rubber-covered traveling cable to a stationary terminal box at the rear of the commutator.

Commutators of the straight-line type on which the brushes pass over the same segments on the up and the down travel require a double-throw switch to open or to close certain circuits. This is necessary so that the signals for a given direction are flashed only when the car travels in that direction. This switch,

shown at S on the control panel in Fig. 41, is a straight-line type. It is operated by two solenoids on the rear of the panel, one at each end of the switch. Energizing one coil throws the switch to one position, and energizing the other coil throws the switch to the opposite position. This switch changes its position automatically at terminal landings upon centering the car switch,

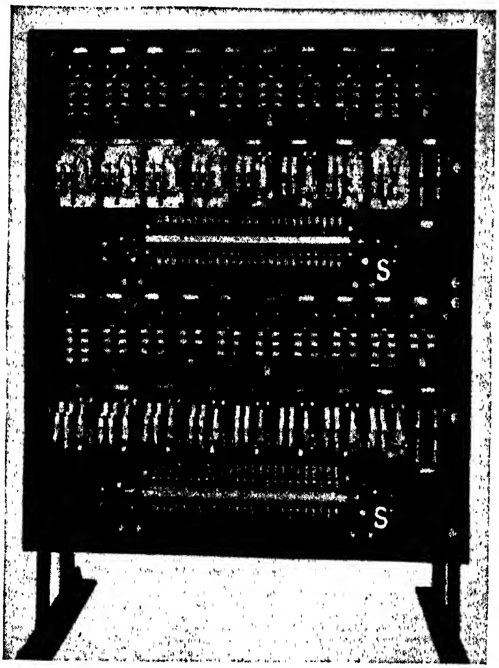


Fig. 41.—This panel, which is for two cars in a group, contains the necessary relays for the proper functioning of the car operator's flashlight, floor lanterns, and reset circuits.

thus insuring proper position of the reverse switch before the car starts. The control panel, Fig. 41, which is for two cars in a group, contains necessary relays for proper functioning of the car operator's flash-light, floor lanterns, and reset circuits.

Master Floor-relay Control Panel.—On the master floor-relay control panel, Fig. 39, there are two relays for each intermediate floor and one for each terminal landing. Each relay unit consists of two coils with an operating armature so arranged that when the release coil is energized, the contacts drop and make the circuit in mercury. These contacts remain closed until the reset coil is energized, when they are pulled out of the mercury and the

armature is latched in the open position. The release or signal-setting coils are connected directly to the landing push buttons. The signal-reset coils are connected to the corresponding reset segments on the commutator, which are cross-connected from commutator to commutator in the standard manner so that the first car to answer the call will reset the signal. This provides a full-selective feature necessary for this class of signal system. When signal installations have either telltale annunciator or night-service annunciators, two independent contacts are mounted on each relay unit, one for 110-volt lamp circuits and the other for low-voltage lamp circuits.

By using the selective system false stops are eliminated. With high-speed elevators considerable time is lost when a car receives a signal, slows down, stops and the doors open, only for the operator to find that another car has received the same signal and picked up the passengers. By preventing false stops elevator schedules can be improved, which means more miles per car in a given time and a greater passenger-carrying capacity, besides a reduction in power consumption per car-mile.

Stopping Cars Automatically at Floors.—At the high speeds at which modern passenger elevators are operated, up to 1,400 ft. per min., it becomes exceedingly difficult for the operator to make accurate landings. The speed of the car makes it hard to recognize floor numbers. At these speeds it is difficult for the operator to judge the distance within which the car can be stopped without going by the floor. This is true even with the best operators, and with the average, much time is lost due to false stops. Even when false stops are few, time is lost owing to the operator's slowing the car down too soon, preparatory to making landing stops.

Where landing doors are interlocked with car position, the latter must be landed accurately before the doors can be opened. When the operator fails to stop the car level with the floor, time is lost while inching it into position. If landing doors are not interlocked with car position, it is necessary that the car be landed accurately to avoid accident due to passengers tripping. Then again, if the car is landed accurately, passengers will tend to move on and off more quickly, since they feel they can do so with safety.

High-speed Accurate Landing.—High-speed accurate-landing elevators, with snappy operating doors have the psychological

effect of causing passengers to move quickly. If accurate landing can be assured, it is possible to render more and better service with a given number of elevators. All these factors may make it possible to reduce the number of elevators to provide this service. In high buildings, increase in renting space due to one or two elevators less adds considerably to the building income.

Accurate landing of car is also an important factor in maintenance of elevator equipment. If it is stopped accurately at the landing on the first trial, ropes are bent only once as they pass over the sheave. If the car goes by a floor and is brought back on one trial, this will cause the ropes to be bent three times in a short section near the sheave. This increased bending in sections near the sheave, corresponding to the car position at landings, causes the ropes to show signs of failing before other sections.

Inching the car puts a heavy duty on magnet switches, particularly with rheostatic control. With normal stopping, current in the direction switches is usually of low value. When the car is moved a short distance to bring it level with the floor, contactors may have to break a maximum current. This wear on contactors can be avoided by stopping the car accurately. Wear on moving parts of equipment, due to the increased number of operations, must also be considered. Most experienced elevator engineers can recall cases where an elevator has run satisfactorily with one operator. Then for some reason a change was made in operators after which the equipment gave no end of serious trouble. No doubt the equipment was not suited to the service, nevertheless it was possible for a good operator to get satisfactory service from it. These experiences are convincing evidence that the operator is an important factor in wear and tear on elevator equipment.

During recent years considerable attention has been given to stopping the elevator car automatically at the landings and thus taking this function out of the hands of the operator. There is much to be said in favor of this practice, as already indicated. In addition, operators are allowed more freedom to attend to passenger needs. If their duties are made such that they can be performed without undue effort, they will be in a proper mental condition to give courteous treatment to passengers. Hard operating doors, a poor signal system, and a control that makes it difficult for operators to make good landings are likely to be reflected in their attitude toward passengers. Such conditions

are important factors in the class of tenant that can be retained in a building. The public is being educated more and more to courteous service, and this is expected from elevator operators just as from the tenant at whose office they may call. If passengers do not get such service, complaints and dissatisfied tenants result. The economic value of the latter is difficult to estimate.

Signal-control Systems Applied to High-speed Machines.—To take full advantage of the high-speed elevator automatic stopping became almost imperative, and it is to handle such service that the signal-control system has been developed. In this system the operator only starts the car, after which it accelerates to full speed and goes to the first floor for which it has been signaled and stops level with the floor. The car gate and doors also open automatically as the car is coming level with the floor, so that when the car stops, the doors and gate are open. This is accomplished in such a manner that there is no danger to the passengers.

Operator's Control Board.—An Otis car-operator's control board is shown in Fig. 42. As passengers come on the car and call the floor they wish to get out at, the operator pushes a button corresponding to this floor. These buttons are shown at the top of the control board. Below these buttons is an operating lever *L*, similar to the ordinary car-control-switch lever. This lever has four positions—off, open, close and start. The open and close position of the lever are for the control of the gates and doors. The start position initiates the starting of the car, after which the lever can be allowed to come to the off position. When the operator starts the car, the operating lever is moved to the start position and the landing doors and car gate close, after which the car starts automatically and the operator has no further action to take until the car stops at the first floor for which a button has been pushed. This button may be in the car or at the floor landings. After the passengers have gotten off or on the car, the operator again pushes the control lever to the start position, when the hatchway doors and car gate close, the car starts and goes to the next floor for which it has been signaled.

Until the car gate is closed and the landing doors are closed and locked, they are under the control of the operator. For example, if the control lever was in the start position and the doors were partly closed, then for some reason it was desired to open them,

the operator can move the lever to the open position, on the right, Fig. 42, and the doors and gate will reverse and move to the open position. It is the closing of the car gate and landing doors and the locking of the latter that completes the control circuit to start the machine.

Car Floor Signals.—On each floor there are two buttons, one for up and the other for down direction. There are also provided on each floor an up and a down signal lamp over the landing door of each elevator. Waiting passengers on a floor push either the up or the down button as they would on the ordinary type of elevator, but instead of signaling the operator to stop at the floor, the controller is set to stop the car automatically at the floor for which the button has been pressed. The first elevator approaching within 30 ft. of the floor, in the direction indicated by the signal will light the signal light and stop at the floor and the landing doors and car gate open, all of which is done automatically. When the doors and gate are again released by the operator, the car starts automatically and answers the next signal registered in the control system either by a waiting passenger or by the operator in the car. In all these operations the only functions performed by the operator are pushing buttons corresponding to the floors called by the passengers in the car and operating the lever that closes the doors and gates and starts the car.

In the car there is only one set of buttons for both the up and the down directions. On the up direction, as the button for the different floors are pushed, they remain in the closed position until the car reaches the slow down at the top landing. As the car is slowed down and stopped at the top landing, all buttons are released and the control placed in position for down motion.

Switches on Operator's Control Board.—Just above the operating lever there are three small switches—safety switch *A*, slow-speed *B*, and non-stop *C*. Moving the safety-switch button down, opens the potential switch on the control board, cuts off the power from the machine and applies a strong dynamic brake to slow the machine down, after which a mechanical brake is applied to stop the machine. This gives a positive stop by a separate means from the ordinary car switch stop.

Pushing the slow-speed switch *B* to the down position cuts out part of the acceleration magnets on the control, so that the elevator cannot come up to full speed. This button is used when it is desired to operate the car at reduced speed.

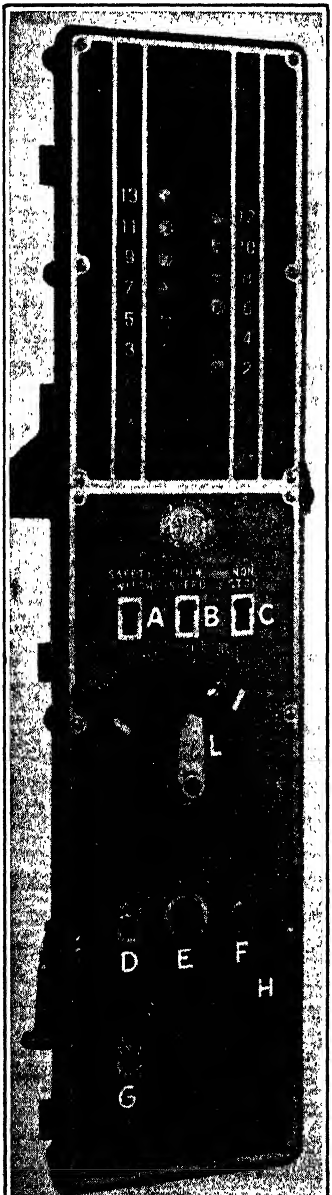


FIG. 42.—Car operating control panel complete with push buttons and switches.

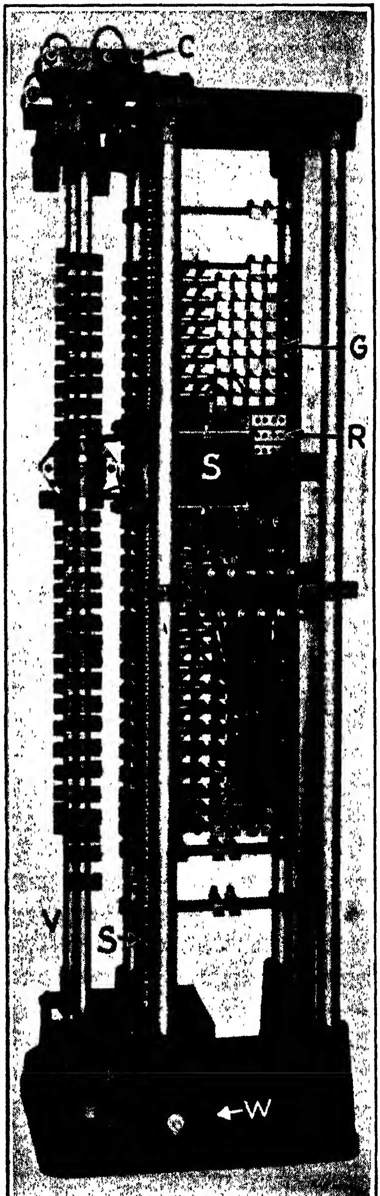


FIG. 43.—Floor selector on which all signals for stopping the car at the different floors are registered.

If the car is full and the operator cannot take on any more passengers, pushing the non-stop button to the down position will bypass the floor signals and the car cannot be stopped by a waiting passenger pushing a floor-signal button. The floor signals, however, are simply switched to the next car following and are not removed from the control system. When a waiting passenger pushes a signal button on a floor, a car must come to this floor and stop before the signal is removed from the control system.

Below the operating lever are three more switches—micro, *D*, emergency cutout, *E*, and light *F*. The machine may be operated at slow speed by throwing the micro switch, which allows the elevator to travel at slow micro speed, and in case of emergency, due to a failure of the main motor or controller, allows the car to go to the landing. The emergency button, which is normally inclosed, and cannot be pushed without breaking a glass cover, is used to bypass the gate contacts, so that the car can be moved with the gates open in an emergency. The light switch is for the lights in the car.

A reverse switch *G* is shown near the bottom of the control board. This is used chiefly when the car is being worked on to reverse the motion without going to the terminal landings. For example, if the car was started from the bottom landing and run to some intermediate floor and then it was desired to return without completing the trip, the reverse switch could be used to set the control buttons for down motion.

At the right bottom of the control board is a red light and lock *H*. These are for the motor-generator set used on what is known as the unit multi-voltage control system. Putting the key in the lock and turning it in one direction starts the motor-generator set, and when it comes up to speed the red lamp lights, after which the key may be removed from the lock. Putting the key in the lock and turning it in the opposite direction shuts the motor generator set down.

A large part of the equipment on the operator's control box is duplicated in the dispatcher's control room. In this room are also indicated the position of each elevator, the direction in which it is going, the waiting-passenger signals indicated from the floor landing buttons and whether the cars are running on a non-stop schedule or answering to the floor calls. If the dispatcher finds that the cars are beginning to close up on one another, he may throw the non-stop switch on one and thereby allow this car to

speed up and gain some headway. If an operator switches to non-stop operation, this immediately shows on the dispatcher's board, so that if he wishes to investigate the cause he may be at the landing to meet the car when it arrives.

Micro-leveling Signal-control Machine.—Figure 44 shows a micro-leveling signal-control machine. The chief difference between this and the standard micro-leveling machine with hand control is the addition of the signal-control equipment, one of the chief parts of which is the floor selector, shown at *E*, Fig. 44, and in Fig. 43. A steel tape runs from the top of the car over a sheave *S*, Fig. 44, down around a tension sheave *B* at the bottom of the hoistway and to the bottom of the car. This tape forms a positive drive for the selector. On the opposite end of the shaft from sheave *S* is a sprocket wheel which connects through a chain to another sprocket wheel on the driving shaft of the selector. In this way any movement of the car is transmitted to the selector and the relation between the two is not affected by any stretch or slipping of the hoist cables. The sprocket wheel *W* on the selector Fig. 43, is geared to the vertical screw shaft *S*, which carries the selector switch *R*. The retardation switches for the floors are operated by two vertical shafts *V*, having a number of U-clamps attached to them, one for each floor. The vertical shafts are connected by bell cranks and a rod at the bottom, and each is mechanically connected to a contactor *C* at the top end.

When a button is pushed in the car or at one of the floor landings, one group of contacts, such as *G*, Fig. 43, is made alive, and when the selector switch *R* has moved onto this group of contacts, the slow-down circuit is completed and coil *S* on the selector is de-energized and releases a pawl that catches under a U-clamp, corresponding to the floor at which the elevator car is to stop. Further movement of the selector switch carries the rods *V* up or down, opens the contactor *C* and completes the process of cutting power out of the main machine. This brings the car within the micro-zone at the floor and the micro machine brings the car level with the floor when the doors and gates open automatically. When the doors and gates are again closed by the operator, coil *S* is energized on the selector and pulls the pawl away from the floor limits and these come to their normal position, allowing contacts *C* to close and the car to start and go to the next floor that has been signaled.

Fig. 44.—Complete installation of a micro-leveling direct-traction elevator equipment, controlled by signal-control system.

Two of the noted installations of signal-control equipments are in the tower of the Standard Oil Company's building and in the Empire State building, New York City. In the Standard Oil installation, group multi-voltage control is used on all signal-control elevators. With group multi-voltage control, a motor-generator set is used to supply 60-, 120-, 180- and 240-volt power to a starting bus. When the elevator motor is first started, it is connected to the 60-volt bus, and as it accelerates

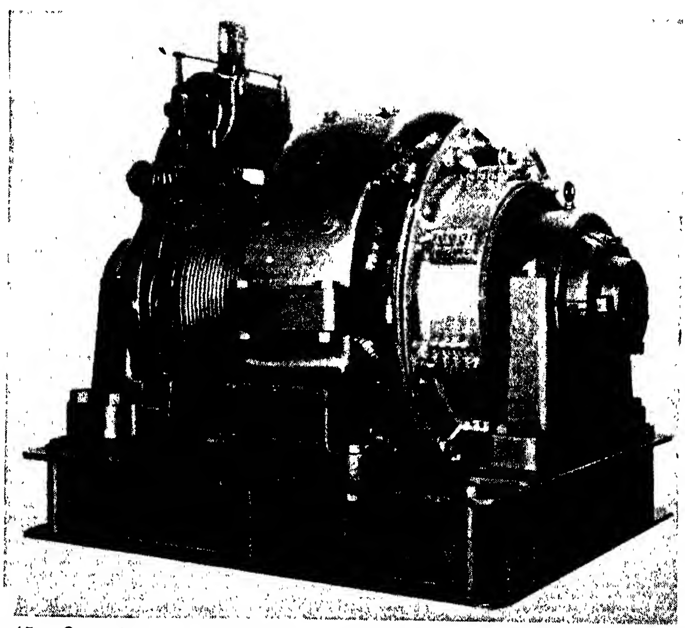


FIG. 45.—One of the high-rise elevator machines in the Empire State building.

it is successively connected to the 120-, 180- and 240-volt buses, the latter being across the line. In this particular installation the multi-voltage is supplied by an automatic substation and in case of trouble on one motor-generator set another is switched in automatically and the machine in trouble shut down in the same way.

In the Empire State building unit multi-voltage control is used; that is, a motor-generator set is provided for each elevator motor. With this type of control the speed of the motor is controlled by controlling the field of the generator similar to the well-known Ward-Leonard adjustable-voltage control.

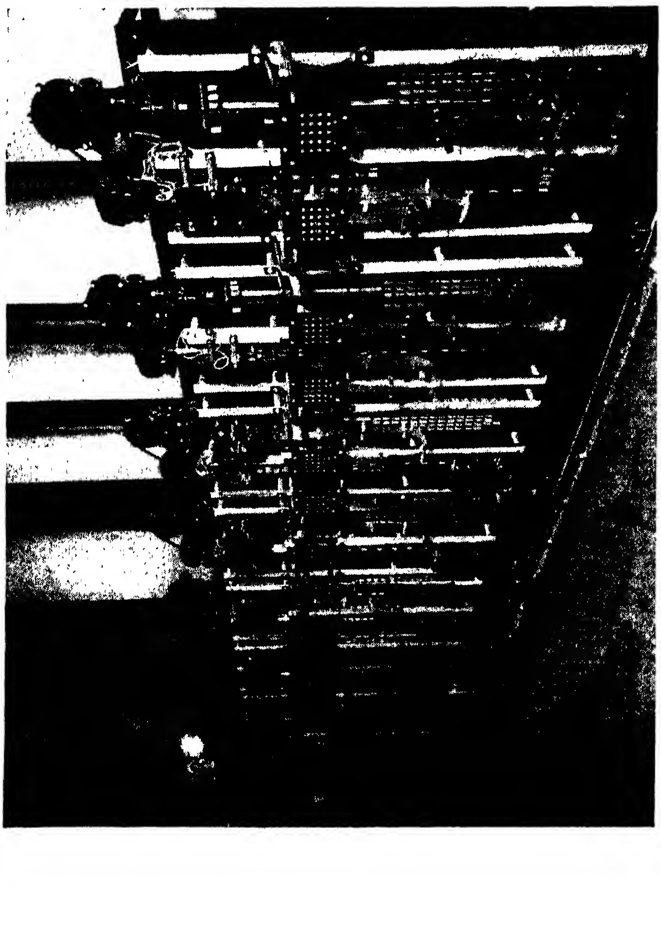


Fig. 46.—Floor selectors for the cars that rise 779 ft. Note their short overall height for that travel.

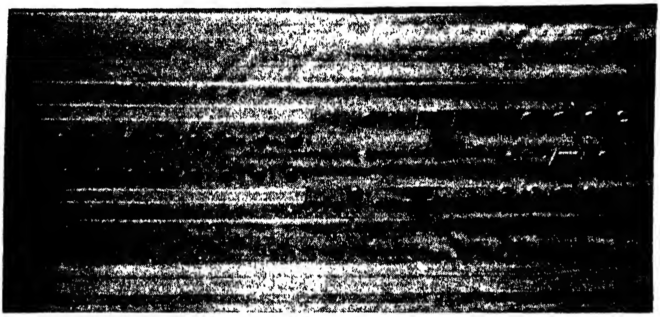


Fig. 47.—Operator's panel in one of the highest-rise cars.

In the Standard-Oil installation leveling is accomplished by a separate motor geared to the main machine as in Fig. 25. A more recent development is one with which the main motor, using unit multi-voltage control, does the leveling, one of the Empire State building machines being shown in Fig. 45.

Automatic Landing, Push-button Control.—In Rockefeller Center main building the elevators are Westinghouse automatic-landing type and the high-rise cars operate at 1,400 ft. per min. Variable-voltage full-automatic control is used and landing is done by the main motor. A new inductor selector having a positive drive and direct ratio between car travel and selector movement was developed. The selector carriage functions only in the zone of the floors served, so that its over-all height is greatly reduced, Fig. 46.

The high-rise cars have a travel of 779 ft. This introduced a problem at the ground floor, due to stretch of the ropes when loading and unloading the car. A stopping and leveling relay, using a photo-electric cell, brings the car back to the floor when it moves away ½ in., because of rope stretch. The car and hoistway doors are protected by the Safe-T-Ray, which automatically prevents them from striking or injuring an entering passenger.

In the cars, the operators' panels are comparatively simple, Fig. 47. There is the usual bank of floor-call buttons at the top of the panel. These buttons are of the lock-in type, but each can be released after being set by a small button below it. On each side of the bank of call buttons are two rows of numerals, one for up direction and the other for down, corresponding to the floor numbers. The numerals are illuminated by the waiting-passenger calls from the different floors. By this means the operator knows at all times on what floors passengers are waiting.

Emergency- and Next-stop Buttons.—Just below the bank of floor stop buttons are three others. The one on the right is to bypass the floor calls, the center one is the emergency stop. If this button is pressed the car will stop as quickly as can be done safely. The button on the left is the next-stop control. If the car is in motion, and for any reason it is desired to stop, by pressing the next-stop button the car will slow down and make a stop at the next landing reached by a normal stop. For example, a 7-floor run is required to make a normal stop from 1,400 ft. per min. If the car were operating at 1,400 ft.

per min. and the next-stop button was pressed, it would stop at a floor 7 floors away from where the next-stop button was pressed.

When the car has been stopped by the next-stop button, it may be started in either direction by pressing the terminal button for the direction desired and moving the control handle to the normal-run position. If the car is running in the up direction when the next-stop button is pressed, then after the car has come to rest, if the bottom terminal button is pressed, the car will start down and operate in a normal manner when the operating lever is moved to the run position. When the car is stopped at an intermediate landing its direction may be reversed by pressing the button corresponding to the opposite terminal from that toward which it was traveling and moving the operating lever to the run position.

At about the center of the control panel are the two operating levers. The one on the right is for normal automatic control. Moving the lever up will close the doors, but the car will not start. This position of the operating lever is intended chiefly for checking operation of the doors and for closing the doors when the car is waiting its turn at the ground floor to take on passengers. When the control lever is moved to the down position, the doors close and the car operates normally under automatic control.

By pressing a button at the bottom of the panel, operation is changed from automatic to manual control by the left-hand operating lever. On manual control the car will run at a maximum speed of about 100 ft. per min.

Below the control levers is a key switch for starting and stopping the motor-generator set and a light that shows red when the set is running. There are three switches in the control circuit of the motor-generator set. One of these is on the starter's panel on the ground floor, one in the car, and one on the control panel in the machine room. All are connected in series, consequently if the motor generator is shut down from one location it cannot be started again until that switch is closed. This arrangement insures against the machine being started unexpectedly when someone may be working on it.

At the bottom of the control panel in the car there are also two switches for control of the fan in the car, a switch for the car lights, a switch for the Safe-T-Ray on the doors, a telephone

jack for use when working on the car and wiring, a buzzer controlled from the starter's panel, a signal reset button, a car- and a hoistway-door bypass under glass and, as previously mentioned, a button to switch from automatic to manual control.

Night-service Cars.—Two of the high-rise cars are equipped for night service. These cars in addition to having an operator's panel for express service, have operating panels for night service. On the night-service panels are buttons and annunciators for all floors not served by express service. A combination control from the night-service and the express panels allows the elevator to serve all floors. The controls on these cars have both an express-service and a night-service selector. To change from the express- to the night-service selector the operator pushes a button on the night-service panel and the change is made automatically. When only the night-service cars are running, by pressing a button on the starter panel, signs are illuminated on each floor that read "Use Night-service Cars."

Dispatcher-type Automatic Control.—In large warehouses, the control of freight elevators have in some cases been made full automatic from push buttons and the control placed in charge of a dispatcher. Those wanting an elevator signal the dispatcher who pushes the button to bring a car, that is not in service, to the floor where it is required. When a car is loaded, the dispatcher is signaled and he sends it to the floor to which the load is to be taken. When the car is unloaded, closing the doors and gates transmit to the dispatcher the signal that the car is available for use. This system of control is known as the dispatcher-type automatic. Such machines are usually equipped with automatic floor-leveling devices to insure easy loading and unloading of the car. This system of control, where it can be used, provides maximum use of the elevator equipment as the machines are under the direction of a single station, where the available machines are indicated at all times.

Department-store Automatic Control.—Department-store passenger elevators are generally stopped at each floor to discharge and take on passengers. For this service a system of automatic control has been developed, known as department-store control. The car gate and landing doors are power-operated and controlled by the operator from a small lever in the car. When the operator closes the gate and doors by moving the control lever to the closed position, the machine starts and takes the

car to the next floor where it is stopped and the gate and landing doors open automatically. The operator's function is to close the gate and landing doors by manipulating the control lever in the car, otherwise the control is entirely automatic and the car stops at every floor.

Collective Control for Apartment Houses.—A collective system of control has been developed for automatic elevators in apartment houses. This type differs from the conventional automatic type of push-button elevator control, in that it will answer all calls automatically no matter if the car may be in service when the landing buttons are pushed to signal the car. For example, assume that a passenger gets on the car at the bottom landing and pushes the button to go up. On another floor other buttons may be pushed by passengers wishing to go up also. When the car reaches these floors it will be stopped automatically for the passengers, and after the doors and gates have been closed it will continue to the floors above for which buttons have been pushed. After the up calls have been answered the machine will then automatically answer the down calls that have been registered in the control system.

In some cases a second car is made to come into service and help take care of the calls when the car in operation has a full load. For instance, assume a full load of passengers gets on the car at the top floor and passengers at some of the lower floors have pushed buttons to be taken down. The car platform is so arranged that the load on it closes contact and the second car comes into service automatically and answers the down calls that the loaded car cannot take care of, and the loaded car responds to buttons only pushed by the passengers in the car.

Power Consumption.—Power consumption of an elevator motor is affected by the type of machine, type of control, the number of stops per car mile and other factors. Tests on five elevators for one year, averaging 180 stops per car mile and using rheostatic control, showed an average power consumption of 8.1 kw.-hr. per car mile. With variable-voltage control and making about 100 stops per car mile, the power consumption was about 4.5 kw.-hr. per car mile.

Using variable-voltage control but in local service making about 370 stops per car mile, the power consumption was about 7.5 kw.-hr., per car mile. In the first instance, the machines had a rating of 2,500 lb. at 600 ft. per min.; in the second, 2,000 lb. at 500 ft.; and in the third, 3,500 lb., at 350 ft. per min.

CHAPTER II

DOUBLE-DECK CARS AND TWO CARS IN ONE HOISTWAY

Double-deck Elevators.—In the Cities Service building eight high-rise, double-deck Otis elevators, operating at 1,000 ft. per min. serve all floors from the twenty-ninth to the sixty-third. These elevators, aside from the two-story arrangement of the cars, are similar to modern high-speed signal-control double-wrap direct-traction elevators now in service throughout the country. The cars consist of two separate compartments mounted in a single frame Fig. 48. They are each driven by a single hoisting machine with a full speed of 95 r.p.m. and are controlled, basically, in the same manner as the standard signal-control elevator. Both compartments are loaded at the same time, one from the ground floor, and the other from the first floor. Passengers are discharged at the upper floors at the same time, one compartment serving only odd-numbered floors, and the other the alternate floors.

Safety Features.—Each compartment is equipped with the standard signal-control operating devices and has an attendant. Trap doors are provided to permit emergency access between compartments and speaking tubes allow communication between them. Clamp-type car safeties are mounted at both the top and bottom of the car-safety frame. These safeties are set to give a positive emergency stop under full load.

Other safety features, common to the ordinary high-speed elevators, include oil buffers in the pit, automatic stopping devices for the top and bottom terminals, and electric contacts to prevent operation until all hoistway and car doors are closed. Because there is occupied space beneath the hoistways, it has also been necessary to provide safeties at top and bottom of the counterweights.

Floor Selector.—The floor-selector part of the control, Fig. 49, performs three important functions: It stops the cars at the floors for which buttons have been pressed; it levels the car at these floors; and it operates the various signals necessary for efficient elevator service. The selector is, to all intents and purposes, a

miniature elevator traveling in a miniature hoistway wherein is grouped the necessary operating equipment. The traveling crosshead that represents the elevator is driven by a steel tape attached to the elevator car and wound on sheaves at the top of the hoistway. An accurate but greatly reduced drive is thus obtained through gear reduction between this tape-drive mechanism and the vertical screw that actuates the selector's crosshead.

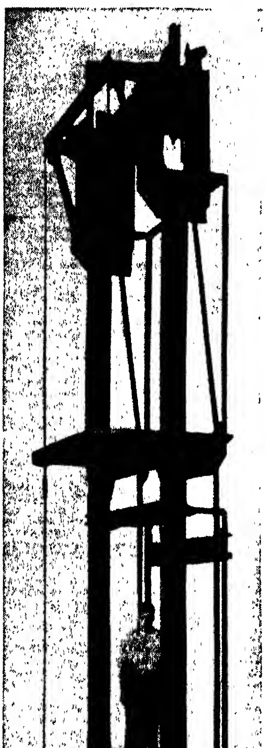


Fig. 48—The frame supporting both compartments of the double-deck cars has an over-all height of 25 ft.

Push-button Control.—Pressure on any hall or car button energizes a corresponding contact on the selector. The crosshead picks up this signal as the car nears the desired floor, and the stopping operation is initiated on the controller. The final stop at floor level is controlled by cams and contacts on the selector. Should the car run by the floor, it is brought back by the same method.

As passengers enter the cars the attendants register their desired floor stops by pressing corresponding buttons in the car-operating panels. When the starting signal is given by the scheduling device, the attendants advance the operating handles, the doors close automatically, and the cars begin their upward trip. Travel continues until the cars automatically stop level with the first landing for which a car or hall button has been pressed. The car and hoistway doors automatically open as the leveling operation is completed. After the passenger transfer, the attendants again advance the operating handles, the doors close, and the cars proceed to the next stop.

Each compartment of the double-deck car is operated by an attendant, and each is equipped with the usual signal-control car-operating devices. The elevator will start only when the operating handles of both compartments are in the full start position and all car and hoistway doors are closed.

The cars will stop level with the desired floors and the doors will automatically open as with standard signal-control operation. If, however, the bottom compartment stops in response to a call for the fiftieth floor, for instance, and no call has been registered for the fifty-first floor, the upper doors will not open and the hall lantern at the latter will not light. If the hall button at the fifty-first floor is now pressed—and the operating

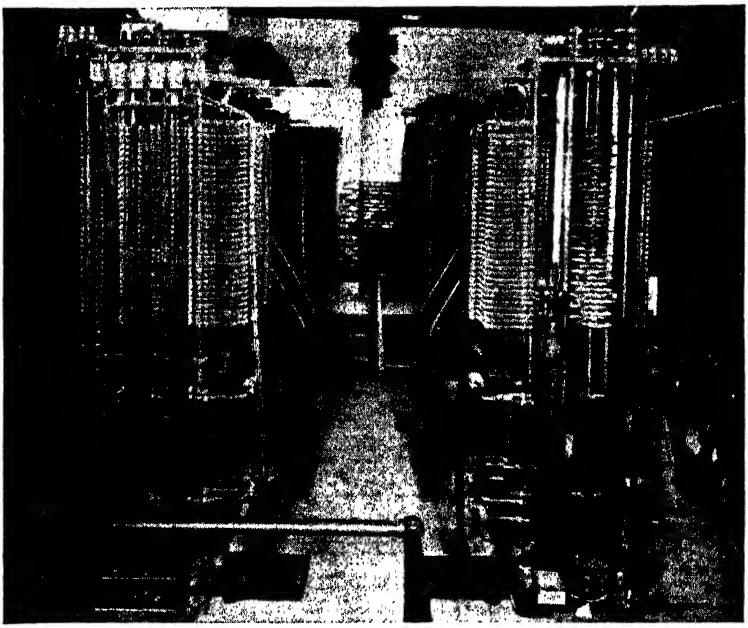


Fig. 49.—Floor selectors for double-deck elevators.

handle in either compartment has not yet been advanced to the start position—the hall lantern at the fifty-first floor will light immediately and the doors will open. If the start has been initiated, the call will be transferred to the next approaching elevator.

Door-pilot Light.—A door pilot light is provided in each compartment. This light is illuminated when the doors for the other compartment open, and is extinguished when they start to close. Each attendant is thus informed when the other compartment is ready to start.

Non-stop Switches.—If one compartment is fully loaded, the operation of its respective non-stop switch will render all hall

calls for this compartment inoperative and transfer them to the next elevator traveling in the desired direction. The hall calls for the other compartment will not be affected and it will stop when signaled, but the doors of the first compartment will not open and the hall lantern will not light. Operation of both non-stop switches will enable both compartments to bypass all hall calls and run express to the ground floors.

In order that both attendants may know when the elevator is scheduled to leave the terminal landings, starting lights are provided in both compartments and operate simultaneously. Individual remote-control switches in the starter's control panel permit any of the elevators to be operated by a single attendant, using the top compartment only. This service does not affect the double-deck operation of other elevators.

Operation as Single-deck Cars.—The operation of a single remote-control switch will allow the entire group of double-deck cars to be run as a bank of single-deck cars. During single-deck service, all operating devices are effective from one compartment only and this compartment stops at all floors, both odd- and even-numbered.

Two Cars in One Hoistway.—The first installation of two independent elevators to operate in one hoistway is in the Westinghouse Electric and Manufacturing Company's office building, East Pittsburgh, Pa. Each car is rated 3,000 lb. at 600 ft. per min. The cars are controlled automatically from a floor-button system. A set of buttons in each car correspond to the floors served. Two sets of buttons at each landing permit calling either the upper or lower car. The top car operates from third to eleventh floors, and the bottom one from first to ninth floors. Headroom provides for parking the upper car during inactive periods and operating the lower car to serve ten floors.

When running two elevator cars in one hoistway safe operation is paramount. Both cars run in the same direction under automatic control, on a fixed schedule. Manual control permits, in an emergency, slow movement of either car toward the other, or if automatic control fails to land the car properly.

Single-car Operation.—When one car operates alone in the hoistway it is stopped automatically before reaching the limits of travel. With two cars operating each car becomes the limit of travel for the approaching car. In general, the same safety

means stop the approaching car before it reaches its limit of travel.

Cars Operate on Block Signals.—The cars normally operate on a block-system control similar to that for subway trains. When one car approaches another it is first slowed down and then stopped by the control used for its normal operation. A green light in the car indicates that it can be run at full speed; an amber light is a caution signal requiring half speed; a red light means stop. These lights guide the operator and indicate one car's position relative to the other.

Safety Devices.—Differential gearing at the top of the hoistway has two elements, one of which is attached to each car by a steel tape. Automatic devices stop both cars if either steel tape becomes slack. The differential gearing operates to slow down and stop the approaching car if the block system fails. This action is selective, and control of the leading car is not interfered with. It can clear the block and provide safe running space for the following car. The approaching car is stopped in three stages by the differential gearing as follows:

1. Electrical connections are made that reduce the car's speed. These make a separate circuit from the normal control circuit, so that it will remain effective even if the normal circuit becomes disarranged.

2. If the car approaches a dangerous position, the emergency stop circuit is completed, applying dynamic and mechanical braking to the elevator machine.

3. Differential gearing connected to the governors reduces the tripping speed of the governor on the approaching car so that its safeties trip if it enters a danger position at an unsafe speed.

Oil buffers stop the cars at either limit of travel. In addition, an oil buffer between the two counterweights prevents shock if the cars drift together, and at the same time emergency switches between the cars disconnect the power.

The two counterweights run on the same set of rails. A safety on the upper counterweight prevents its dropping on the lower one in event the ropes break.

The car safety is set by a very small movement of the car after the governor trips. Initial jaw pressure against the rail is applied by a spring. Further movement of the car causes them to grip the rail with increasing force. Normally, the first appli-

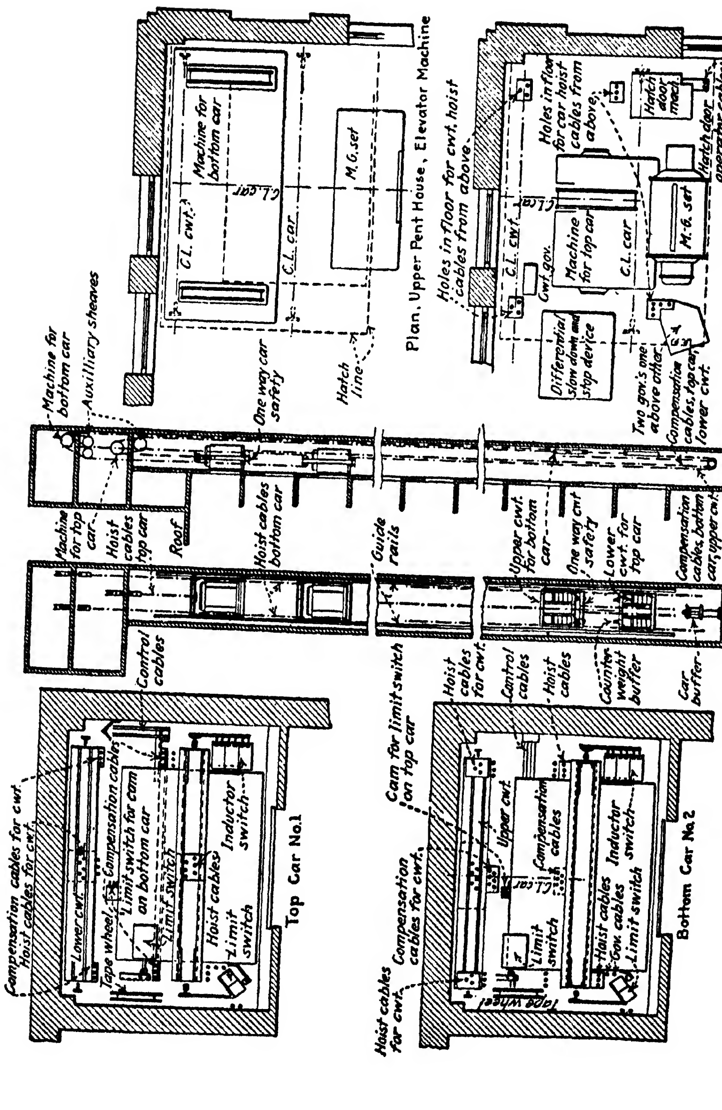


FIG. 50.—Plans and elevations of the two elevators in one hoistway.

cation of the safety will stop the car without severe strain on the passengers. A safety switch in each car allows the operator to set the emergency circuit if necessary.

Method of Roping.—Arrangement of the hoisting, compensating ropes, and electrical cable connections are given in Fig. 50. When designing this hoistway, considerable clearance was provided around the cars, difficulty being anticipated in arranging ropes and cables. Experience gained on this installation shows that the hoistway size can be reduced but dual elevators will require more clearance than a single-car installation.

Lower-car hoisting ropes lead down each side of the top car and are attached to the bottom-car crosshead at each end on opposite sides of the guide-rail line. The other end of the hoisting ropes connects to the outer ends of the counterweight. Distance between counterweight rails is approximately the same as between car rails. The top counterweight connects to the bottom car.

On the top car the hoisting ropes attach at the crosshead center and lead to the bottom counterweight through a slot in the upper one. This arrangement is similar to a drum-type machine using a separate car counterweight. The bottom-car compensating ropes connect to the top counterweight. The top-car compensating ropes pass down either side of the bottom car and attach to the ends of the bottom counterweight.

Aluminum Parts.—Aluminum is used wherever reduced weight improves operation. Car slings and platform framing are made of aluminum. A combination of aluminum and micarta gives the car inclosures an unusual and attractive appearance. The saving in weight of the cars and slings reduces power required to operate the machines and decreases stresses in equipment and supporting structure.

CHAPTER III

ALTERNATING-CURRENT MACHINES

Converting Alternating Current into Direct.—Where alternating current only is available, there are two methods of applying it to elevator service. The first of these is to convert it into direct current, either by a motor-generator set or rotary converter, to supply all the elevators in the building from a common source. In this arrangement any of the direct-current types of elevator equipment may be used that employs a rheostatic type of control. With this type of control the motor is started with a resistance in series with the armature which is cut out of circuit automatically as it comes up to speed.

Another way of converting alternating current into direct for elevator service is to use multi-voltage control. In this method an induction motor is used to drive four single direct-current generators, or two double direct-current generators. These generators are wound for one-quarter of the elevator motor's rated voltage. On starting, the motor is connected to one generator and receives one-quarter full voltage through a suitable starting resistance. As the motor's speed increases, it is disconnected from this generator and connected to two in series, thus applying one-half full voltage to the elevator motor. The two generators are then disconnected from the motor and it is connected to three machines in series, after which it is connected to the four generators in series, when it comes up to full speed on full voltage. This type of equipment is used for high-speed traction-elevator service, and a group of elevators may be supplied from the same source.

Still another method of converting alternating current into direct and applying it to elevator service is to use the so-called variable-voltage (Ward Leonard) control system, which is coming into general use for high-class high-speed elevator applications. In this system an individual direct-current generator driven by an alternating current motor is used for each elevator motor.

The speed and direction of the elevator are controlled by the generator field. This type of control is described in Chapter XV. In some installations one alternating-current motor is used to drive two direct-current generators, one for each of two elevator motors. The individual motor-generator set for each elevator is the preferred method, since if anything happens to the motor-generator set, only one elevator is affected, which makes for greater reliability.

Applying Alternating Current.—The second method of applying alternating current to elevators is to use alternating-current motors and controllers. This involves a number of different schemes, but none of them is applicable to high-speed elevator service, such as is obtained with the modern direct-traction machines. When this class of service is required, involving car speeds above 500 ft. per min., variable voltage with direct-current motors probably offers the best solution to the problem. For car speeds less than 500 ft. per min.. alternating-current motors and controllers are probably the most economical in most installations. Alternating-current motors and controllers have been used successfully by one manufacturer for car speeds up to 700 ft. per min., but what the outcome of this development will be, it is too early to predict.

Alternating-current motors and controllers as first applied to elevator service were not very satisfactory, because they were not properly designed for the work and were noisy. These difficulties have been largely overcome in modern equipment. In the simplest type of alternating-current equipment a high resistance squirrel-cage motor is used with suitable type of control for connecting and disconnecting and reversing the motor. In some cases the motor is connected directly to the line, while in others a resistance is connected in series with the stator until the motor has had an opportunity to get under way.

Squirrel-cage Motors.—It might be stated here that an induction motor with a single squirrel-cage winding cannot be designed to have both a high torque and high efficiency. To obtain high efficiency the resistance of the rotor must be low, but a low-resistance rotor has a low starting torque. To obtain a high starting torque, the resistance of the rotor winding must be high and this results in a low efficiency. The average general-service motor is a compromise between a motor of high efficiency and one of high torque.

General-service squirrel-cage motors of comparatively high efficiency and low starting torque were the first used on elevator service, but experience has shown that high torque is of vastly more importance in this class of work than high efficiency. In cases where the earlier types of motors have been replaced by modern high-torque, low-efficiency motors, designed for elevator service, the power consumption has been reduced as much as 50 per cent.

Torque Required for Starting.—Experience has shown that on a worm-geared type of machine it requires about 200 per cent as much torque to start the machine with a full load in the car as it does to hoist the load. Therefore, to be on the safe side, the motor should be capable of developing about 250 per cent of the torque necessary to lift full load in the car. In an alternating-current motor the torque varies as the square of the voltage, so that if the voltage is reduced 10 per cent, the motor's torque will be reduced to 81 per cent of that at normal voltage, and allowance must be made for this in selecting the motor. Motors of such high torque, under normal conditions of load, will accelerate the car so quickly as to give an unpleasant jerk to the passengers. To overcome this difficulty it is quite general practice to connect a resistance in series with the stator's winding at the instant of starting. After the motor has had an opportunity to get under way, the resistance is cut out of circuit by a time-limit or current-limit contactor.

Type of Controllers on Slow-speed Elevators.—Preference seems to be given to the time-limit principle in controllers for alternating-current motors. With the current-limit type, if the contactors are set so that they will close when hoisting full load, they will close too quickly on light loads. Or, if set to give good light-load acceleration, the contactor will not close when heavy loads are being hoisted. Although the time-limit contactor does not give all the desirable features, it is in many respects superior to the current-limit type on the kind of control required for alternating-current elevator motors. In some cases, on controls with a number of accelerating points, a compromise has been made and time limit used on the first contactors to close and current limit on the last to close.

Where the elevator's speed is less than 100 ft. per min., the motor can be started by connecting it directly across the line. With higher speeds than this, a resistance in the starter circuit is

generally required on squirrel-cage motors, particularly if the elevator is used for passenger service. It has been found in practice, that if a high-torque motor will start without causing any unpleasantness to the passengers in the car, it will accelerate smoothly to full speed, so that one step of starting resistance is all that is required for slow-speed elevators.

Wound-rotor Motors.—In the past wound-rotor motors have been used quite extensively on elevators, in which case the control was arranged to cut out the rotor resistance in a number of

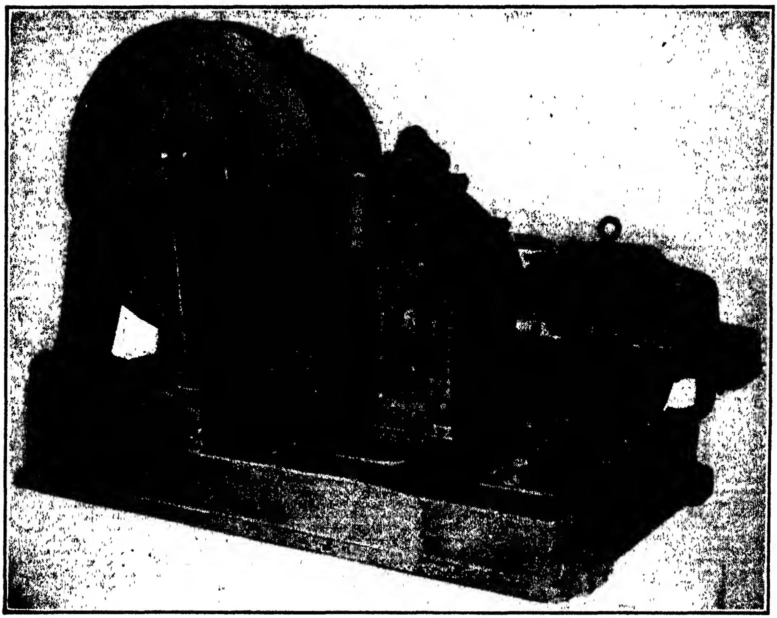


Fig. 51.—Geared traction machine driven by wound-rotor motor.

steps. A traction machine, built by the A. B. See Electric Elevator Co., driven by a wound-rotor motor, is shown in Fig. 51. During recent years the trend has been toward the use of high-torque squirrel-cage motors. These motors have a high-resistance winding on the rotor and develop their maximum torque at standstill. One objection to the use of such motors is their poor speed regulation. The speed in hoisting full load may be 20 per cent below synchronism, while in lowering full load it will be 20 per cent above. On a motor having a synchronous speed of

720 r.p.m., this means a variation of 280 r.p.m. between hoisting full load and lowering a load of equal amount.

Multi-speed Motors.—Although a good operator can make good landings at a car speed of 150 to 200 ft. per min., it is desirable to get the speed down to at least 60 ft. per min. before cutting the power out of the motor. In freight service this may be as low as 10 ft. per min. On direct-current machines the speed of the car can be taken care of in the control equipment and almost any desired landing speed can be obtained. With alternating-current motors, when lowering a heavy load, connecting resistance

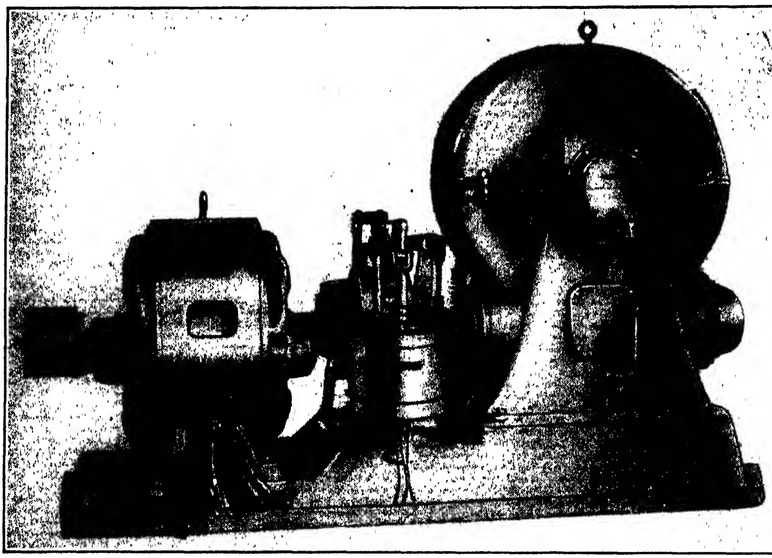


FIG. 52.—Geared traction passenger machine driven by two-speed motor.

in the stator or rotor circuit will cause the car speed to increase instead of decrease. During such load conditions the motor is acting as a generator and is supplying power into the system. If resistance is connected into the circuit, the motor's speed will have to increase if a given current is to be maintained to the line and a braking action developed by the motor to keep the car under control. For this reason the car must be landed from the full speed if a single-speed motor is used. This condition puts a limit of about 100 to 150 ft. per min. on car speeds for single-speed motors. For speeds higher than this, two-speed motors are used, which are in general of the squirrel-cage type.

Some of the elevator manufacturers use multi-speed motors for practically all car speeds.

Motors of this type are built in three different forms. First, with a single winding arranged for regrouping to give different speeds. These motors are limited to speed changes not exceeding 1 to 4 by regrouping the winding through suitable control equipment for two different numbers of poles—for example, 24 and 6 poles. On a 60-cycle circuit the 24-pole grouping would give the motor a synchronous speed of 300 r.p.m. and the 6-pole grouping a synchronous speed of 1,200 r.p.m.

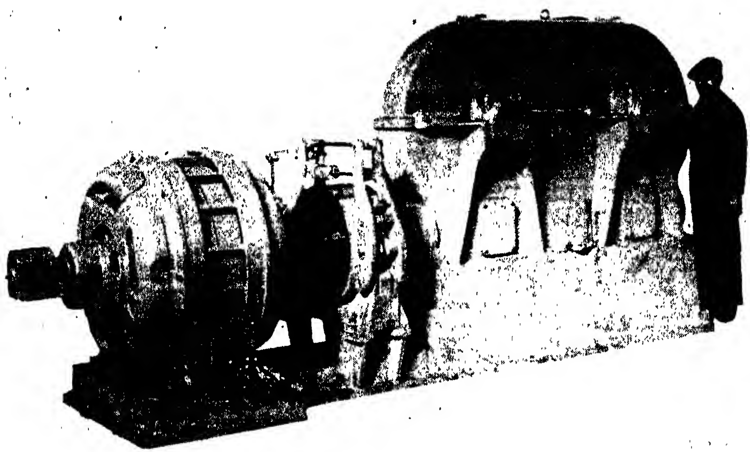


Fig. 53.—Tandem-geared heavy-duty freight machine driven by two-speed squirrel-cage motor.

The second method of obtaining a two-speed motor is to wind the stator with two separate windings in the same slots. The windings are grouped for a different number of poles, such as 24 and 6, which would give the same speed ratio as for the single-winding machine. Motors of this type have been built for speed changes of as high as 1 to 6. For example, if on the slow-speed winding the motors run 150 r.p.m., on the high-speed winding they would operate at 900 r.p.m. Motors of this type have been built for operations on elevators having a car speed of 700 ft. per min., such as the machine of the Haughton Elevator Co., shown in Fig. 52.

A tandem-geared machine, Fig. 53, built by the same company, has a rating of 30,000 lb. at 150 ft. per min., or 15,000 lb.

at 300 ft. per min. A motor speed ratio of 1 to 6 is used, and the motor is rated at 150 hp. The V-grooved traction sheave has 8 grooves for $\frac{3}{4}$-in. cables. On the larger-capacity machines, above 15,000 lb., the roping is 2 to 1 where the smaller-capacity machines are cabled direct. Sheave diameters of 42 to 48 in. are used, depending upon the capacity and speed of the machine. When a 1 to 6 motor is used, whether in freight or high-speed passenger service, the motor speed range is always 150 to 900

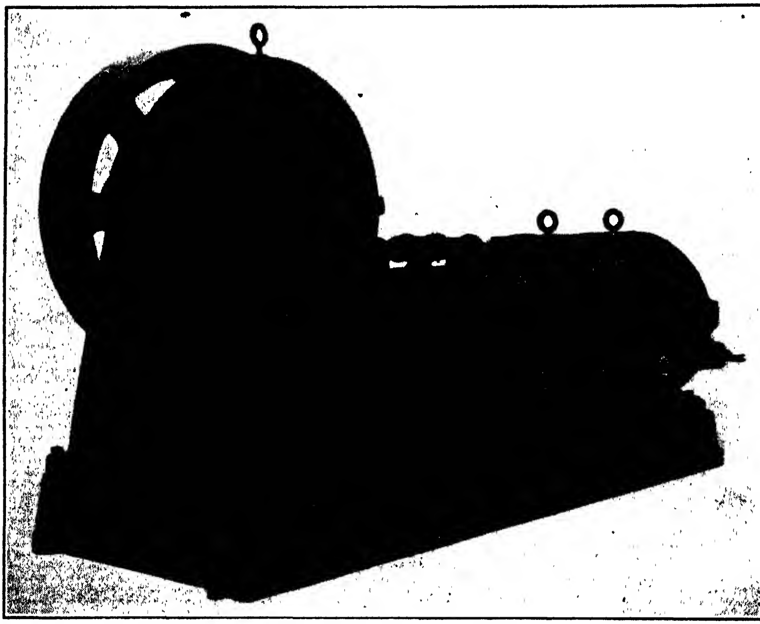


FIG. 54.—Traction machine driven by a double squirrel-cage motor.

r.p.m., the different car speeds being obtained either by changes in gearing, size of traction sheave, or in roping arrangement. For all speeds above 350 ft. per min. the roping is direct and never compounded.

A third type of two-speed motor is one that consists of two separate motors included in the same frame. One of the stator cores has a winding grouped for, say, 16 poles and the other carries a winding grouped for 4 poles. Such an arrangement would give a speed change of 1 to 4. Motors of this type are limited in speed range by the same factors as the double-winding motors. In the double motor the two rotors are keyed on the

same shaft without any coupling between them. An equipment of this type, built by the Turnbull Elevator Co., Ltd., is shown in Fig. 54.

Limitations of the Different Types of Multi-speed Motors.—The first type of motor being restricted to speed ratios of 1 to 4, is limited to where the car speed does not exceed about 400 ft. per min. Another disadvantage claimed against this motor is that one grouping of the winding must be disconnected before the other can be made and connected to the line. During this transition period there is a possibility of losing control of the car. This claim is probably not by any means as much of a hazard as might at first appear, since, so far as the author has been able to determine, no trouble of this sort has ever been reported on an elevator operated with a single-winding two-speed motor, and there are hundreds of them in service.

The single-winding two-speed motor has the advantage that all the material in the motor is in use at all times, therefore, for a given capacity machine it can have smaller dimensions than the two-wind machine, or the double type. For this reason the rotor of the single-winding machine has lower flywheel effect, consequently the motor will have a lower energy consumption and cause less wear on the brake mechanism than the two-winding motor. The two-winding motor is at a disadvantage when repairs are made to the stator winding, if the damaged winding happens to be at the bottom of the slots.

The chief advantages of the double motor are that the slow-speed motor can have a high resistance squirrel-cage winding on the rotor, and the high-speed motor can have a wound rotor with external resistance, thus providing for high efficiency and good speed regulation.

A wound-rotor could be used in the single-winding and double-winding type motors, but this would add greatly to the complication of the control equipment. The rotor winding would have to be arranged so that it could be grouped for the same number of poles as there are in the stator, and when one was regrouped by the control equipment the other would also have to be regrouped. This makes a control equipment so complicated that any advantages that the wound-rotor motor may have are lost. In the earlier development of the alternating-current elevator, multi-speed wound-rotor motors were used to some extent, but their application to this class of service has been practically abandoned.

Methods of Starting Two-speed Motors.—Two methods of starting two-speed motors are employed: One, all the starting is done on the high-speed winding and the slow-speed motor is used only for stopping. If an induction motor is running at a speed above synchronous when connected to the source of power, it will develop a braking effect and slow down to normal speed, which is due to the motor's acting as a generator. When stopping an elevator from high speed, operated with a two-speed motors, the high-speed winding is disconnected and the low-speed connected. This gives a dynamic braking action and causes the elevator to slow down to a speed corresponding to the normal slow speed of the motor, before the mechanical brake is applied to bring the car to rest after the power is cut out of the slow-speed winding. This method great'y reduces the work that must be done by the brake, therefore it can be much smaller than it would be if it had to stop the elevator from high speed. It also allows the operator to bring the elevator down to a speed where good landing stops can be made.

The other method of starting two-speed elevator motors is to use the slow-speed winding for both starting and stopping. At starting the low-speed winding is cut into circuit and the elevator accelerated to near the normal speed for this winding, when the high-speed winding is cut into circuit and the slow-speed cut out. In stopping, the cycle of events is the same as when starting is done on the high-speed winding only, as previously explained.

When stopping on the slow-speed winding, it is generally necessary to connect a resistance in series with this winding to prevent the slow-down action of the motor being too abrupt, giving an unpleasant jerk to the car and unduly straining the equipment. As an example of what happens when a motor is connected to the line when operating at a speed above normal, a motor of good characteristics for elevator service, with a resistance connected in series with the stator winding, sufficient to allow the motor to develop 100 per cent full-load torque at starting, will produce a negative torque (braking action) equal to 450 per cent full-load torque if connected to the line when operating at 175 per cent synchronous speed. If the motor was connected directly to the line for slow down, the dynamic action would be much higher and would have objectionable effects on the elevator operation. For a detailed explanation of a two-speed controller's operation see Chapter XIII.

The squirrel-cage motor, either single-speed or two-speed types, seldom gives trouble due to overheating when applied to average elevator operating conditions. When the starts per hour are excessive, as may be the case with elevators serving department stores, and when the operating speeds are high, overheating may result with this type of motor. The reason is that it must dissipate, internally, the accelerating losses as well as the full-speed losses which are relatively high due to the slip.

Another type of two-speed motor has been developed for severe elevator service, by the General Electric Company. This machine comprises a high-speed slip-ring induction motor

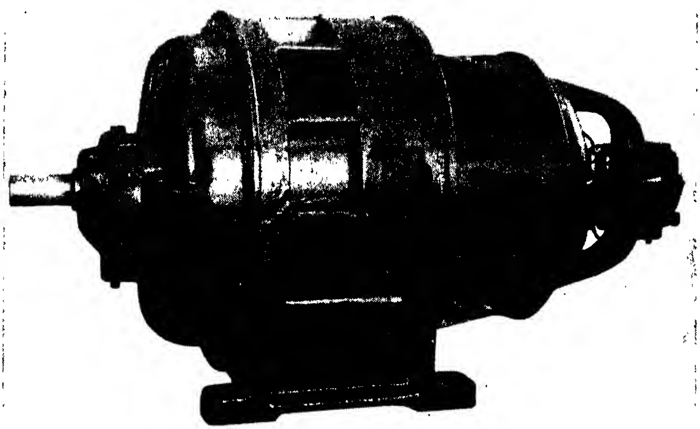


FIG. 55.—Two-speed motor comprises a high-speed slip-ring induction motor mounted with a slow-speed squirrel-cage motor.

mounted with a low-speed squirrel-cage motor, Fig. 55. The slip-ring section is used for acceleration and full-speed running, while the squirrel-cage section provides the landing speed. Since the acceleration losses are largely dissipated externally in a resistor, and as the motor has a low slip, its full-speed losses are correspondingly low. This type combination motor, or tandem motor, will stand a large number of starts per hour without overheating, and is built for 4 to 1 and 6 to 1 speed ratios.

Single-phase Motors.—In some few cases single-phase motors have been used on elevators, but this has been only when polyphase current was not available. The single-phase motors in these applications have been of the repulsion type.

Commutator-type Polyphase Motors.—Adjustable-speed commutator-type polyphase motors have been used in Europe and two installations made in Canada. These were made by the Turnbull Elevator Company, of Toronto, Canada, in the Queenston power plant of the Hydro-Electric Power Commission of Ontario at Niagara Falls. These elevators have a lift of about 300 ft. and operate at a speed of 450 ft. per min. and are probably the only installations of the kind in Canada or the United States.

This type of motor has two sets of brushes on the commutator, which are moved in opposite directions to change the speed. The

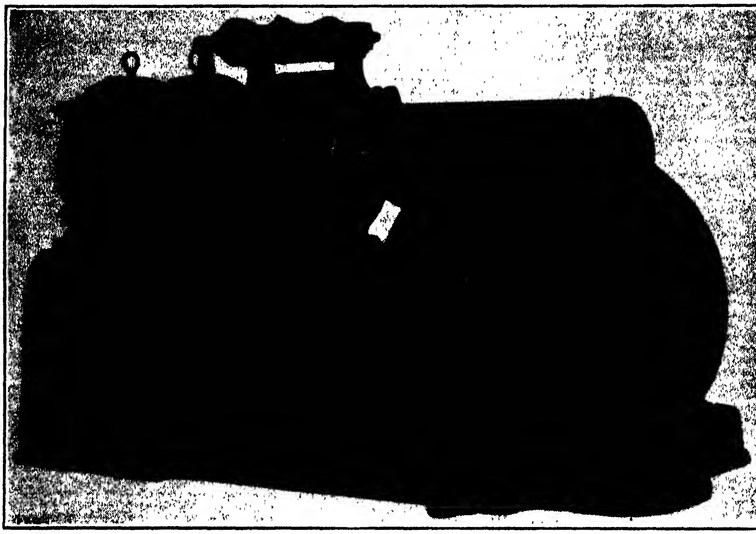


Fig. 56.—Traction machine with worm over gear driven by squirrel-cage motor.

lowest speed is obtained when the two sets of brushes are in line, which in the installation in question gives a car speed of 150 ft. per min. As the two sets of brushes are separated, the speed is increased. This is done in elevator installations by a torque motor mounted on top of the main motor. A torque motor is a small machine of special characteristics that permits it to be left in a stalled position with line voltage applied. This torque motor shifts the brushes to the high-speed position and lifts a weight, which will return the brushes by gravity to the low-speed position if the power to the torque motor is cut off.

In operation some good features and some unsatisfactory ones were found with this equipment. The speed transition is smooth,

and is fully as good as that obtained from a variable-voltage equipment, within the speed range that was attempted, which was 450 ft. per min. at high speed to 150 ft. per min. at low speed. The speed-torque characteristics of the motor are good, especially for an alternating-current motor. It was found that the torque output per ampere input increased during acceleration in a way similar to that of the compound-wound direct-current motor.

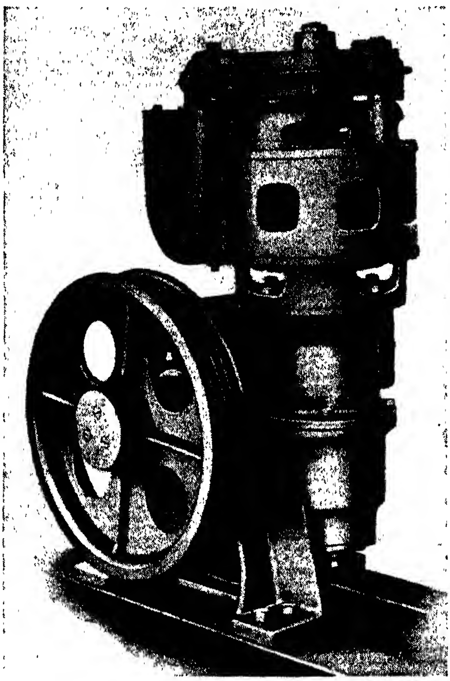


FIG. 57.—Small, vertical-type elevator machine driven by squirrel-cage motor.

The disadvantages of this equipment are: First, the high price of the motor, which compares unfavorably with a variable-voltage motor outfit of the same size and speed; secondly, the large and heavy rotor, which makes the WR^2 of the motor high and the acceleration slow; a third disadvantage is that of noise. The commutator, which is large, has a large number of narrow segments and a great many brushes about $\frac{1}{8}$ in. thick.

Worm-over-gear Principle.—In general, the gear wheel is located above the worm of worm-gear drives for elevators. A V-grooved traction-type machine with the worm over the gear, as

built by the Turnbull Elevator Company, is shown in Fig. 56. The general impression is that the lubrication on machines of this type is unsatisfactory, but the experience of this company has been that it is more satisfactory than where the worm is located below the gear. The explanation is that the oil is carried up by the pockets of the gear teeth and is then thrown out by the worm

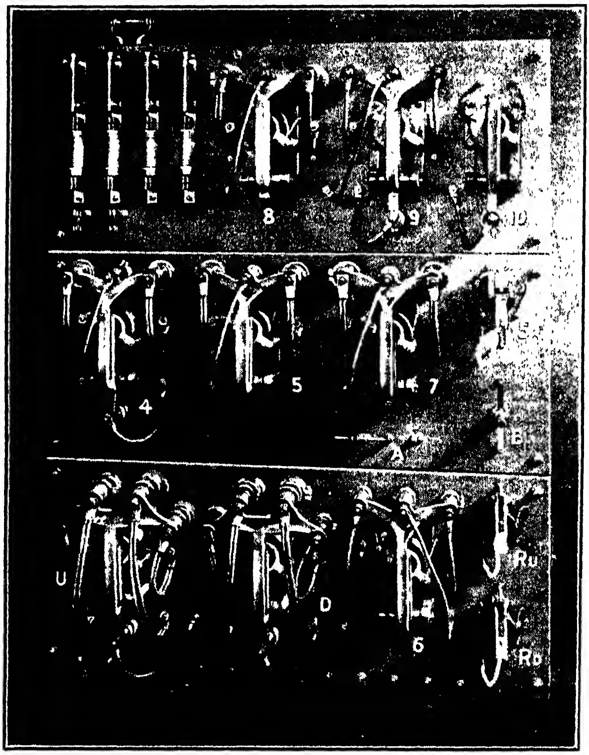


FIG. 58.—Two-speed squirrel-cage motor controller with dry-type magnets.

and runs down the outer walls of the gear housing and is cooled in a manner not possible when the worm is below the gear.

Another modification of the usual worm-gear arrangement is shown in Fig. 57. This is a small-capacity A. B. See traction machine constructed with the worm shaft and motor vertical, for installation in small space. The motor is a single-speed squirrel-cage type, but the machine is also built for direct-current motor drive.

What has been said previously regarding the mechanical details of elevator equipment operated by direct-current motors applies equally to elevators operated by alternating-current motors, with the exception of the high-speed direct-traction machines which are not used with alternating-current motors.

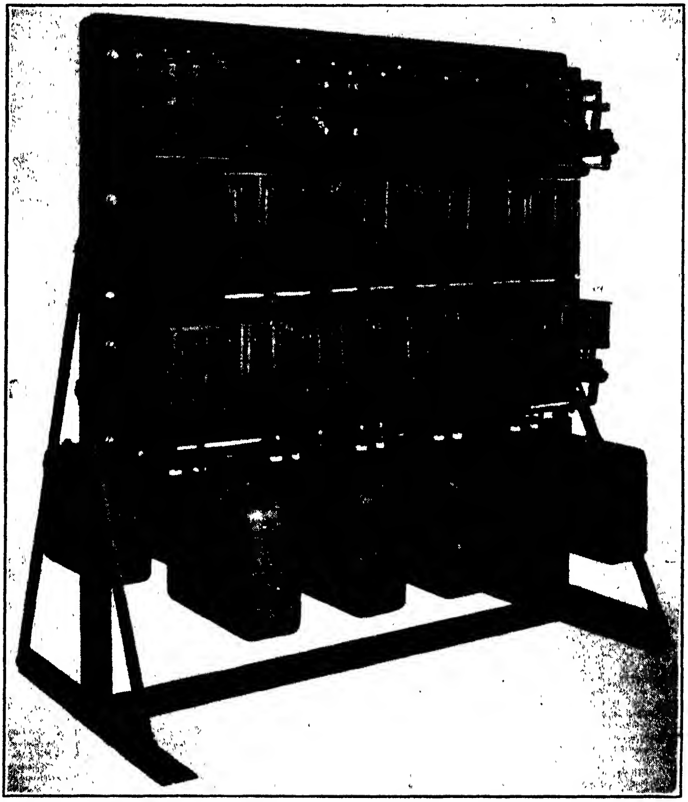


Fig. 59.—Two-speed squirrel-cage motor controller with oil-immersed magnets.

Types of Controllers for High-speed Machines.—In many of the controllers used, the contactors are operated by magnets in much the same way as on direct-current controllers, except that the magnet cores are made of laminated iron or steel to keep down the eddy currents and prevent excessive heating of the cores. In general the magnets are of the dry type such as used in direct-current work. A Gurney Elevator Company controller of this type, for the control of a two-speed motor, is shown in Fig. 58.

To a limited extent direct-current controllers have been used on alternating-current motors, the current for operating the controller being supplied from a small motor-generator set. This

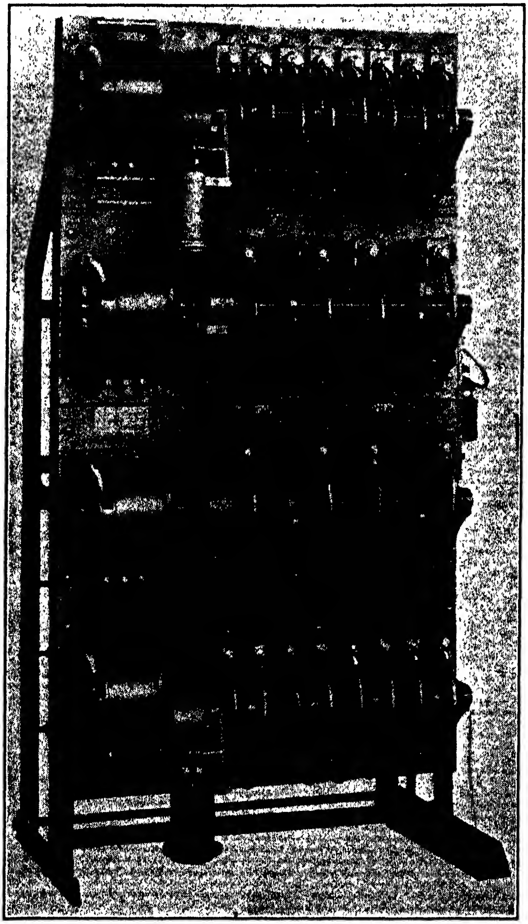


FIG. 60.—Two-speed squirrel-cage motor controller with torque-motor magnets.

was done to get away from the noise and other difficulties that were prevalent with the earlier types of alternating-current magnets.

On some makes of alternating-current controllers the magnets are immersed in oil, as those on the Turnbull Elevator Company's two-speed motor equipment Fig. 59. The oil pots containing the magnets are at the bottom of the panel board. Immersing

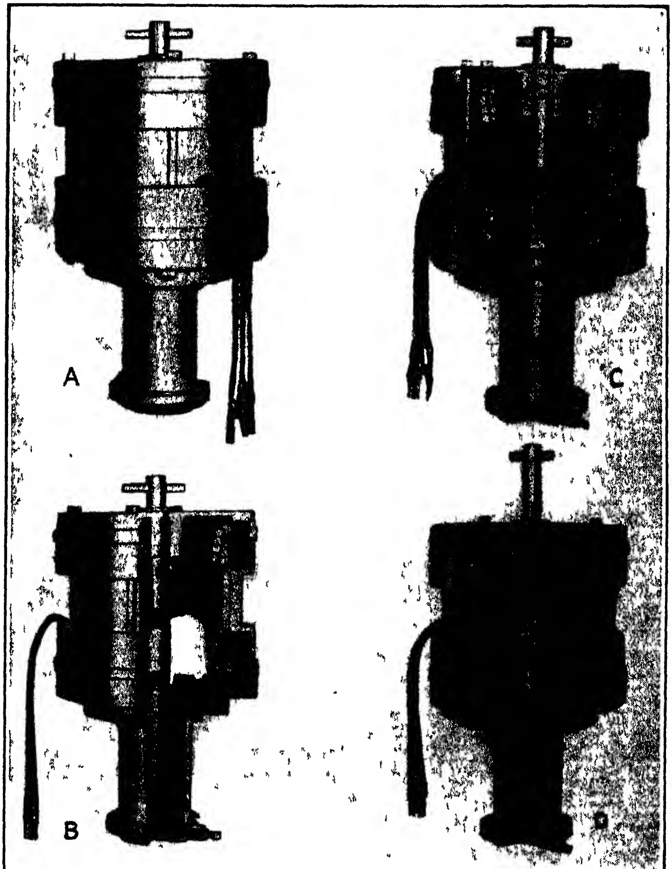


Fig. 61.—Complete assembly and sections through a non-sealing type polyphase brake magnet.

A—Complete assembly of brake magnet. *B*—Section through magnet's stator and plunger *C*—Section through stator showing plunger in released position. *D*—Section through stator showing plunger in full-stroke position.

the magnets in oil helps to keep them cool and quiet and insures lubrication.

Rotating types of magnets are also used. These are simply polyphase torque motors which are controlled from the car switch, and when this switch is closed to the up or the down position, the motor rotates and closes the contactor for a given direction. Figure 60 shows a Haughton Elevator Co.'s two-speed

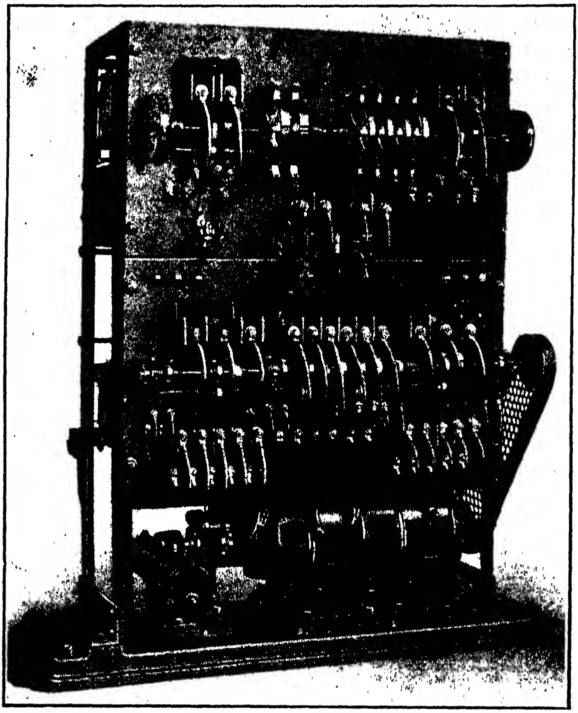


FIG. 62.—Voltage-regulator type controller for two-speed squirrel-cage motor.

squirrel-cage motor controller of this type. The torque-motor type magnets are shown on the left of the figure. These magnets have a constant pull over their entire range of action. They also have the desirable feature of taking a constant current, therefore do not take a large inrush current common to other types of alternating-current magnets. Because the magnet's core does not seal on closing, the magnet is known as a non-sealing type. This company also uses rotating type magnets on its direct-current motor controllers. A polyphase brake magnet of the non-

sealing type is shown in Fig. 61. This magnet, although of the polyphase revolving-field type, is reciproacting in its operation instead of rotating.

Induction Regulator Control.—A recent development in alternating-current controllers is that made by the Otis Elevator Company, in which an induction-type voltage regulator is used to apply the starting voltage gradually to the motor, which is of the two-speed type. Figures 62 and 63 show the controller

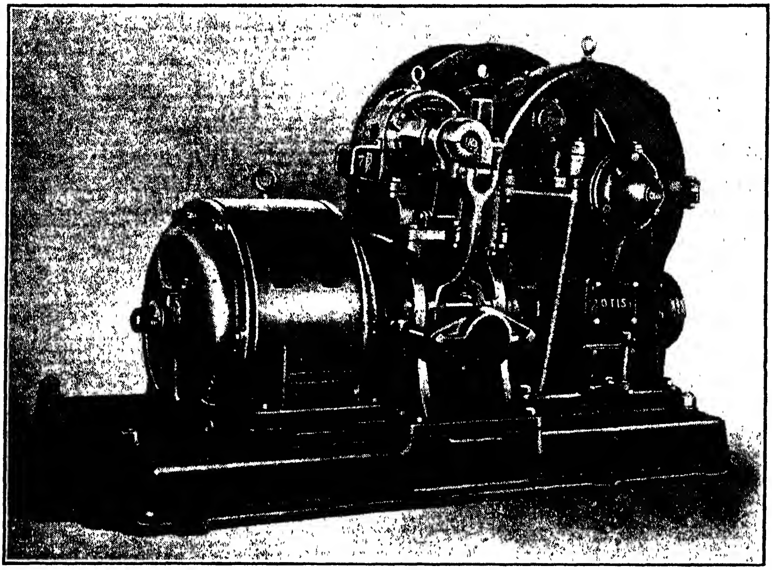


FIG. 63.—Geared type traction machine driven by two-speed squirrel-cage motor controlled by voltage-regulator type controller.

and the elevator machine respectively. Since the voltage is gradually built up at the motor terminals during starting without steps, the acceleration is very smooth. No resistance is connected in the motor circuit at starting, voltage control being accomplished by the regulator, and all starting is done on the high-speed winding. This arrangement provides an efficient method of acceleration, as there are no starting resistance losses. These equipments have been built for speed ratios of 4 to 1 and car speeds up to 400 ft. per min.

Just below the controller Fig. 62 can be seen the combination induction voltage regulator and torque motor. The torque motor, which is on the right, turns the regulator's rotor to raise

the voltage and also operate the transfer switches on the bottom half of the panel board. A time element in the movement of the regulator is provided by a double dashpot, shown at the left-hand end of the regulator. Torque motors are also used to operate the direction switches at the top of the controller.

On the elevator machine a single-winding high-resistance squirrel-cage motor is used. This winding is arranged for regrouping to obtain two speeds. The brake is spring actuated and is released by a torque motor specially designed for this purpose.

CHAPTER IV

METHODS OF ROPING AND THEIR EFFECTS ON LOADING OF THE CABLES AND BEARINGS

Drum-type Machines.—For a given weight of car and load the method of roping-up the machine has a considerable effect on the loading of the cables and the bearings. Practically all earlier types of electric elevator machines were of the winding-drum type, but, in present-day practice this type is being rapidly superseded by the traction types. On the drum-type machine there are generally three sets of cables. One set, the car cables, has one end attached to the car and the other to the winding drum; a second set, the drum-counterweight cables runs from one of the counterweights to the drum; the third set connects the car to the car counterweights. All these are clearly shown in Fig. 64 for a basement-type installation.

The overhead drum-type elevator installation, Fig. 65, simplifies the roping considerably and requires only about one-half the length of cables from the car and from the counterweights to the drum. The car counterweight cables are about the same length in either installation. The general arrangement of the cables is clearly shown in the figure, where the car and drum-counterweight cables lead off opposite sides of the drum, with the car counterweight cables passing over the vibrating sheave and to the counterweights. When the drum spans less than half the width of the shaft, a deflecting sheave is required to lead the counterweight cables vertically down the shaft.

These types of machines are limited to relatively short rises of about 150 ft. or less. For higher rises the drum becomes of an unwieldly length to provide space on which to wind the cables. With a drum of given diameter a different length is required for each height of travel of the car. For example, on a 100-ft. rise a drum would have to be provided that would have space for winding up 50 ft. more cables than on a 50-ft. rise.

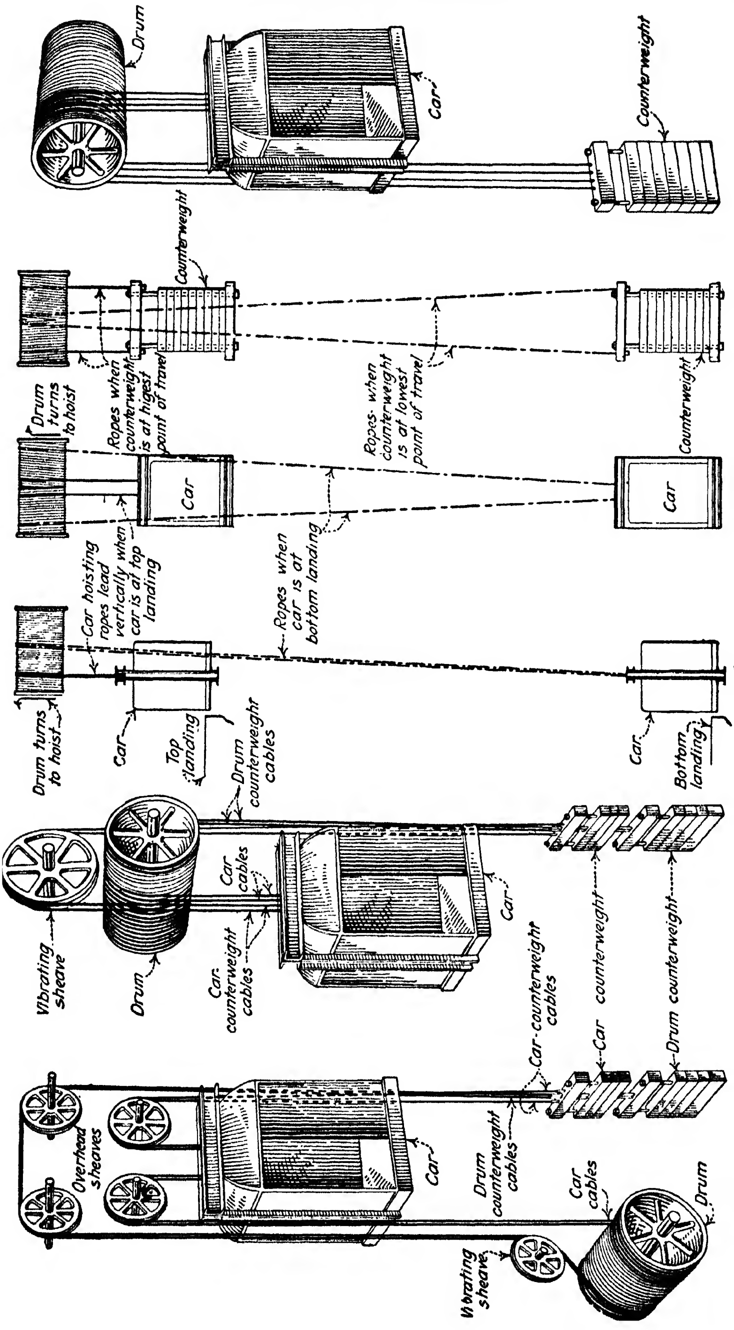
Another objection to the drum-type machine is that in case the limit and control devices fail to cut the power out of the motor

at the terminal landings, the car or counterweights may be pulled into the overhead work. In such an event the cables may be pulled out of their sockets and the machine wrecked.

With the overhead-type machine, Fig. 65, the cables have to bend in only one direction when winding on and off the drum, and as there is no creeping, long life of the cables is assured under normal conditions. When such machines are installed in the basement, as in Fig. 64, reverse bends are encountered, as the cables bend around the different sheaves, which tend to shorten the cables' life.

In an overhead installation, because the cables travel along the drum as they wind on or unwind off, there is only one point in the car and counterweight travel where they exert a vertical pull. At all other places in the shaft a side pull is applied to the car and counterweights. The effect as applied to the car is indicated in Fig. 66, which shows that if the cables pull vertically on the car at the top landing, at every other position there is a side pull. This is also true for the counterweights. To avoid this side thrust in high-rise installations, a single spiral groove is sometimes used on the drum, and one-half of the drum is grooved right-handed and the other left-handed. One of the two car cables is attached to each end of the drum and the two counterweight cables at the center, as in Figs. 67 and 68. From these figures it can be seen that although the cables lead off from the vertical, one opposes the side thrust of the other and the result is a vertical pull on the car and counterweights at all positions of travel.

Drum-type Traction Machines.—What might be considered as a transition in the design between the drum-type elevator machine and the traction type is an arrangement known as the drum-type traction drive. This machine uses a single spiral U-groove drum. The cables run from the car and are given 1½ or 2½ wraps around the drum; then they go to the counterweights, as shown in Fig. 69. The cables are not fastened to the drum in any way and depend upon their friction in the grooves to hoist the car or counterweights, as the case may be. In their operation on the drum the cables act as so many nuts having 1½ or 2½ turn threads on a bolt. As the drum turns the cables travel from one end of the drum to the other in much the same way a nut travels along a bolt. Since the cables bend in only one direction they have a long life under normal conditions.



FIGS. 64 to 69.—Different methods of roping up drum-type elevator machines.

This type of machine has the same objections as the winding-drum type; namely, a side pull is applied to the car in all but one position in the shaft, different lengths of drum are required for different heights of maximum car travel, and in high rises the drum becomes long and unwieldly. A limit switch is provided to stop the motor as the cables approach the end of the drum. Although the machine cannot pull the car or counterweights into the overhead beams, if for any reason the safety limits were to fail there would be a bad piling up of the cables at the end of the drum, which might result in serious consequences.

Full-wrap Traction Machines.—Traction-elevator machines, as they are generally known, may be divided into two general classes, full-wrap and half-wrap. · In order to obtain sufficient traction between the cables and the traction or driving sheave, with U-shaped grooves, a secondary or idler sheave is used as in Fig. 70. The sheaves have parallel U-shaped grooves instead of spiral grooves as used on the winding drum of drum-type machines. In Fig. 70 the cables run from the car over the traction sheave down around the idler sheave, up over the traction sheave again and to the counterweights. This gives the effect of a full wrap on the traction sheave, from which this type of traction elevator gets the name, "full wrap."

From four to six cables are generally used, and the traction sheave always requires twice as many grooves as there are cables. To prevent excessive strains being set up in the cables, the sheaves should not be less than 28 in. in diameter.

With the traction type, a standard machine can be used irrespective of the length of car travel. If the car or counterweights land on the bumpers at the bottom of the pit, the traction is lost between the cables and sheaves, so that neither the car nor counterweights can be pulled into the overhead work. Therefore, if the limit devices failed, the only thing that could happen would be for the car or counterweights to land and the motor keep running and turn the traction sheave in the cables until the power was cut off. There are cases on record where the sheave has turned for two or three hours in the cables with no more serious results than badly worn grooves in the traction sheave and wearing of the cables.

Where the diameter of the traction sheave is equal to one-half the width of the hoistway, the secondary sheave may be placed directly under it, as in Fig. 70. In installations where one-half

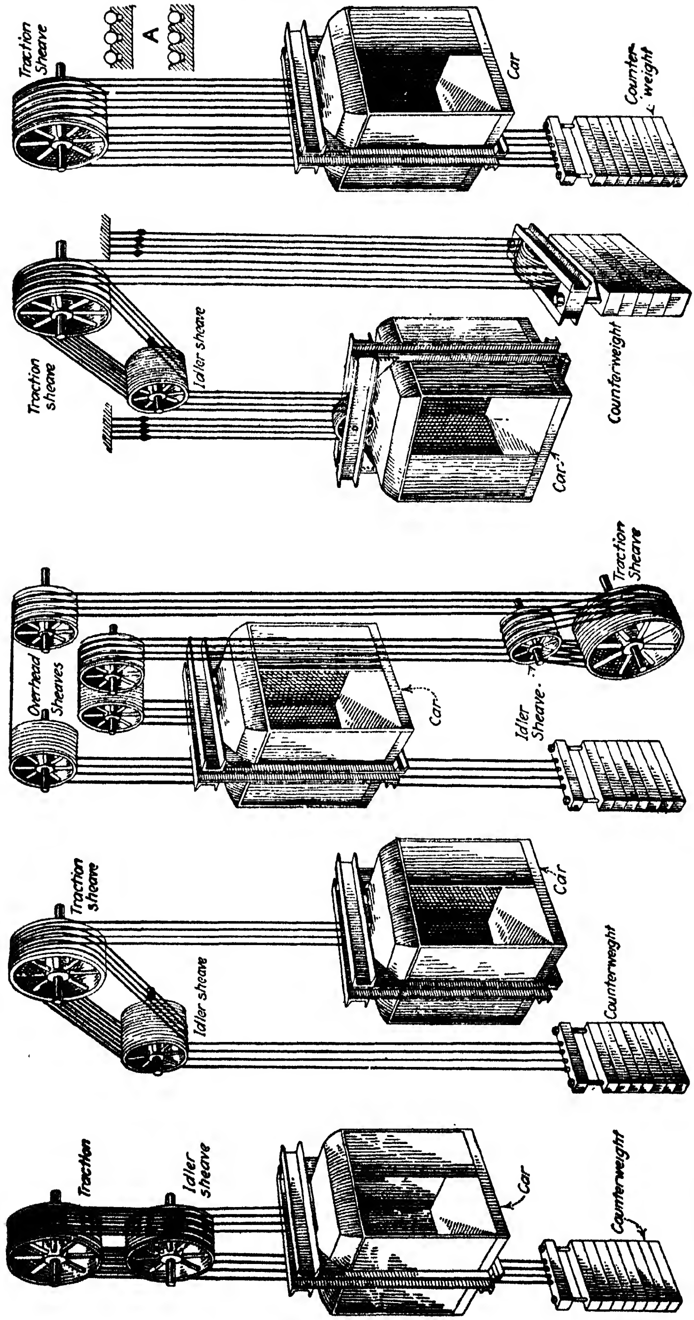


Fig. 70. Fig. 71. Fig. 72. Fig. 73. Fig. 74.

Figs. 70 to 74.—Different methods of roping up traction-elevator machines.

the width of the hoistway is greater than the diameter of the traction sheave, then the idler sheave also serves as a deflector to lead the cables vertically down to the counterweights, Fig. 71.

Cable Arrangement on Basement-type Traction Machine.—In most cases traction elevator machines are located overhead. When it becomes necessary to install the machine in the basement, a roping up arrangement is used similar to that shown in Fig. 72. This requires a somewhat similar arrangement of overhead sheaves as with the basement-type drum machine and also causes reverse bends in the cables. About twice the amount of cable is required for this installation as for the overhead, and the additional sheaves make the cost considerably more than for the overhead installation. Furthermore, the cable life will be shorter and the power consumption higher, consequently the operating expenses will be greater than for the overhead machine. For these reasons the basement-type installation should be avoided whenever possible.

Roping-up of 2-to-1 Traction Machines.—In the traction-type installations so far considered, the speed of the car and counterweights is equal to the peripheral speed of the traction sheave. This is what is called a 1-to-1 roping, in that the car and cable speed are the same. Where it is desirable to use a direct traction-elevator machine, that is, a machine in which the traction sheave is mounted directly on the motor shaft, and a car speed is required that is lower than can be obtained with a 1-to-1 roping, a 2-to-1 roping may be used as in Fig. 73. This arrangement is also used on some classes of geared-traction machines, where very slow car speeds are required, such as on heavy freight and automobile elevators.

With a 2-to-1 roping the car speed is only one-half that of the rope speed. Instead of the ends of the cables being attached to the car and counterweights, as on the 1-to-1 roping, they are dead-ended to the overhead beams. From one of the dead ends the cables pass around an idler sheave in the car crosshead and then around the traction and secondary sheave, then around an idler sheave in the counterweight crosshead and to the second dead end, as in Fig. 73.

Since one-half the weight of the car and the counterweight is carried on the dead ends, Fig. 73, the loading on the traction and secondary sheave is only about one-half that for the 1-to-1 machine, Fig. 71, consequently a lighter construction can be used.

From Fig. 73 it will be seen that the cables make three reverse bends. This results in a shorter cable life for the 2-to-1 than for the 1-to-1 overhead installation.

Half-wrap Traction Machines.—A type of traction machine that is coming into wide use is that known as the half-wrap, the roping scheme of which is shown in Fig. 74. In this type of installation the cables pass from the car over the traction sheave to the counterweights, so that there is only a half wrap of the cables on the sheave. The traction sheave has some form of a wedge-shaped groove which grips the cables by virtue of the wedging action between the sides of the grooves and cables. Two types of the grooves are shown at *A* in the figure.

This type of installation gives one-half the loading on the traction sheave that is obtained with the full-wrap machine for the same weight of car load and counterweight, consequently the former can be constructed considerably lighter than the latter. With the one-half wrap installation there are a minimum number of bends in the cables, which tend toward long cable life. This, however, is offset to a considerable degree by the pinching action of the grooves on the cables, but cable life is generally a little longer on the half-wrap machine than on the full-wrap installation. For the same capacity and speed the same machine may be used for any height of car travel. If the limit switches fail to function, the car or counterweights will land on the bumper, when the traction between the cables and sheave will be relieved and the cables will not be strained or pulled out of the sockets, as is likely to be the case for a drum-type machine.

As the grooves wear there is a tendency for the pinching action on the cables to be reduced. This is not a serious factor in the machine's operation since sheaves have given 8 to 10 years or longer continuous service without experiencing any difficulty from wearing of the grooves.

Effects of Worn Grooves in Traction Sheaves.—A feature of either the full-wrap or half-wrap installation that must be given careful consideration is the condition of the grooves. When one groove wears more than the other, the cable in the groove with the shortest periphery will have to slip a certain amount to have the same speed as the other cables. This slippage not only wears the cable, but it also wears the grooves and tends to make conditions worse. When the grooves become worn so that their peripheries are not the same length, they should be trued up in a lathe. This

work is sometimes done by mounting a lathe tool and rest on the machine and turning the sheave with the motor. If the sheave is too badly worn, it will have to be replaced. Where fiber packed sheaves are used, as in Fig. 23, uneven wearing of the grooves is repaired with a tool as shown in Figs. 269 and 270.

When the diameter of the traction sheave is less than one-half the width of the car in the half-wrap installation, a deflecting sheave can be used to guide the cables vertically down the shaft to the counterweights, as with the full-wrap installation, Fig. 71. The limit of deflecting the cables off the sheave is about 45 deg. from the vertical. When sufficient span cannot be obtained in this way, such as with wide freight cars, it will be necessary to use a full-wrap installation.

There are many other schemes that have been used in roping-up elevator installations, but those given in the foregoing have come into most common use and will include probably over 99 per cent of all electric elevators in use.

Load on Cables without Counterweight on Drum-type Machines.—The simplest form of a winding drum-type of elevator machine is that shown diagrammatically in Fig. 75. This consists of a car of some kind connected by a cable to a winding drum. The objection to this cable arrangement is that the motor must be large enough to lift the total load including the weight of the car. The cables are subjected to the full load and the brakes must be strong enough to stop the total load in the down motion, including the weight of the car.

For example, if the car weighs 2,500 lb. and the rated load is 2,500 lb., then the motor would have to be of a rating capable of operating the machine when lifting 5,000 lb. The loading on the cable and overhead sheave would be as indicated. It will be noticed that the cables are subjected to a loading equivalent to the weight of the car and load and the overhead-sheave bearings are loaded to double this value plus the weight of the sheave. If the drum is driven by a worm and gear, the rear thrust bearing will be subjected to a load equal to the weight of the car and its load. When stopping the car in the down motion, the loading on the thrust bearing will greatly exceed the weight of the car and its load.

The great difference between stopping the machine without a load in the car and when fully loaded, especially in the down motion, makes this arrangement very unsatisfactory. Further-

more, in the up motion the motor must always be lifting at least the weight of the car, and in the down motion there will always be at least the weight of the car driving the motor as a generator and pumping back into the electric system which results in an unnecessarily large power consumption.

Load on Cables When Drum Counterweight Is Used.—The arrangement of roping shown in Fig. 76 overcomes some of the objections to the scheme in Fig. 75. Here a counterweight is used and its cables attached to one end of the drum and the car cables to the other. In the up motion the counterweight cables unwind and the car cables wind in the same grooves, whereas in the down motion the reverse action takes place. It is general practice to make the counterweight equal to the weight of the car plus 40 per cent of its rated load. Applying this rule to the car and load in Fig. 76 makes the weight of the counterweight equal to $2{,}500 + (2{,}500 \times 0.40) = 3{,}500$ lb., as indicated. With this arrangement the motor has to be large enough to lift a load equal to $5{,}000 - 3{,}500 = 1{,}500$ lb. This weight, 1,500 lb., is also the loading on the rear thrust bearing with full load in the car. Instead of the brake having to be large enough to stop and hold a load of 5,000 lb. when the car is in the down motion fully loaded, it need only be of sufficient capacity to take care of 1,500 lb. With 1,000-lb. load in the car it is about balanced by the counterweight so that very little power is required to move it in either direction. In the down motion with full load in the car, the motor will only have to resist a load of 1,500 lb. to prevent the machine from racing. All these conditions help to make the machine more efficient in power consumption.

Adding the counterweight has not, however, reduced the loading on the car cables, which is the same in both cases. On the other hand, the counterweight has increased the loading on the overhead beams 7,000 lb. plus the weight of the additional sheave, making it $10{,}000 + 7{,}000 = 17{,}000$ lb. plus the weight of the sheaves. Another factor is that the loading on the drum-shaft bearings has been increased from about 7,070 to 8,630 lb. This, however, does not take into consideration the downward loading due to the weight of the drum or the upward thrust of the gear out of the worm. It will be noted that instead of the loading on the drum-shaft bearing being in a vertical direction, it is at an angle to the vertical, due to the combination effect of the vertical lift of the car and counterweight cables and the

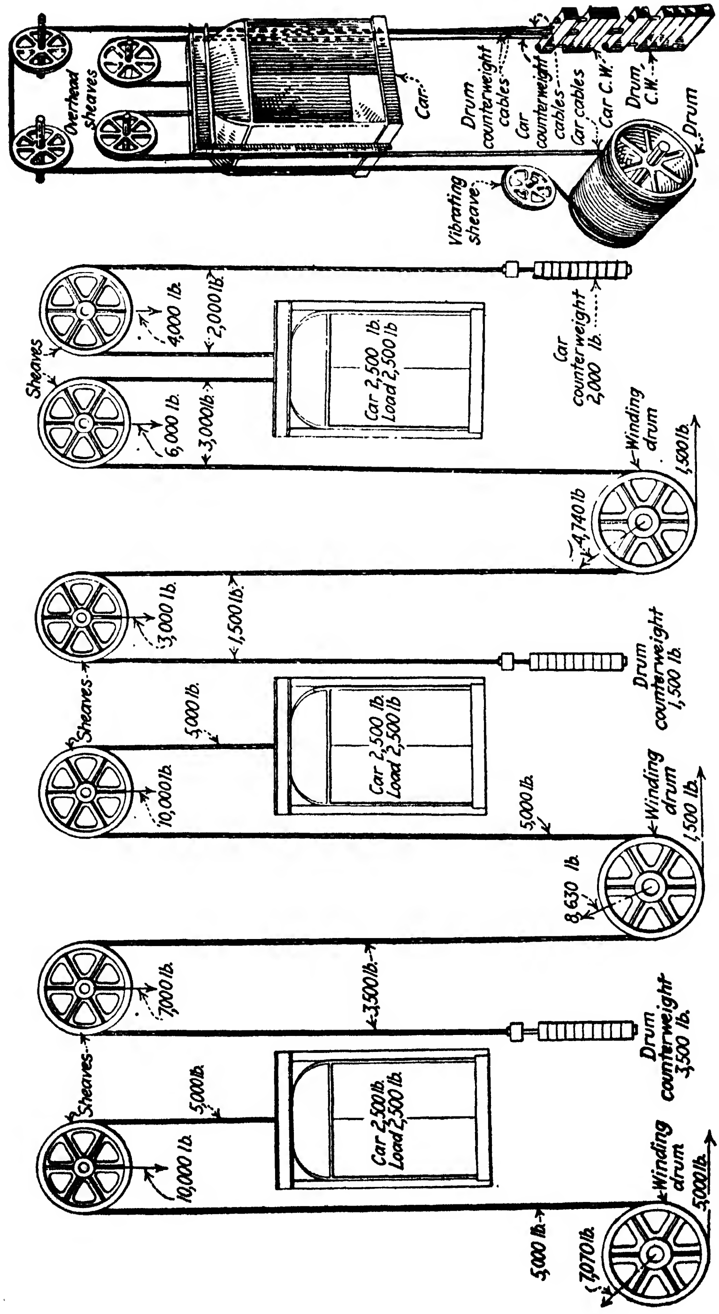


FIG. 75. FIG. 76. FIG. 77. FIG. 78.

FIGS. 75 to 78.—Show distribution of load on basement-type drum elevator machine and cables.

horizontal force transmitted from the worm and gear. The loading on the thrust bearing is based on the assumption that the worm gear is the same diameter as the drum. Where the gear is of a smaller diameter than the drum, the loading will be increased on the thrust bearing and on the drum-shaft bearings.

Loading When Car and Drum Counterweights Are Used.—By using a second counterweight, called a car counterweight, as in Fig. 77, part of the weight of the car can be removed from the car cables and drum and the weight of the drum counterweights can be reduced, which will also remove part of the load from the drum-shaft bearings. It is general practice to make the weight of the car counterweight from 300 to 500 lb. less than the weight of the car. By making the car counterweight equal 500 lb. less than the weight of the car gives a weight of 2,000 lb. and reduces the drum counterweight 2,000 lb. Then, 4,000-lb. load would be taken off the drum shaft, besides removing 2,000-lb. load off the car-hoisting cables. The loading on the thrust bearings will remain the same as in Fig. 76, as will the size of the brake, but the load on the overhead work has been reduced from 17,000 to 13,000 lb. or a reduction of 4,000 lb. This reduction in weight on the overhead beams would be affected somewhat by the sheaves, but it is evident that the counterweight scheme, Fig. 77, has a distinct advantage over the arrangements Figs. 75 and 76. It is for these reasons that the counterweights on drum-type elevators are arranged as in Fig. 77, although in practice the two sets of counterweights are generally arranged to run in the same guide rails, with the car counterweight above the drum counterweight, as in Fig. 78.

Overhead Drum Type Machines.—At first thought it might appear that placing the elevator machine overhead would cause a much heavier loading on the overhead beams than when the machine is located in the basement. Consideration of Fig. 79 will show that this is not necessarily so. For example, with the same load, weight of car and counterweights, the load on the overhead beams due to the car and counterweight is only 8,500 lb., in Fig. 79, as against 13,000 lb. plus the weight of the shaves in Fig. 77, or a difference of 4,500 lb. plus the weight of the sheaves. So that, if the machine Fig. 79 weighed 4,500 lb., the loading on the overhead beam would be about the same in both cases. In some installations the loading on

the overhead beams is less with the machine placed overhead than it would be with the machine in the basement.

Half-wrap Type Traction Machines.—Traction elevator machines are usually placed overhead as in Fig. 80. In the simplest type, the cables pass from the car over the traction sheave and to the counterweight. On the traction sheave, V-shaped grooves

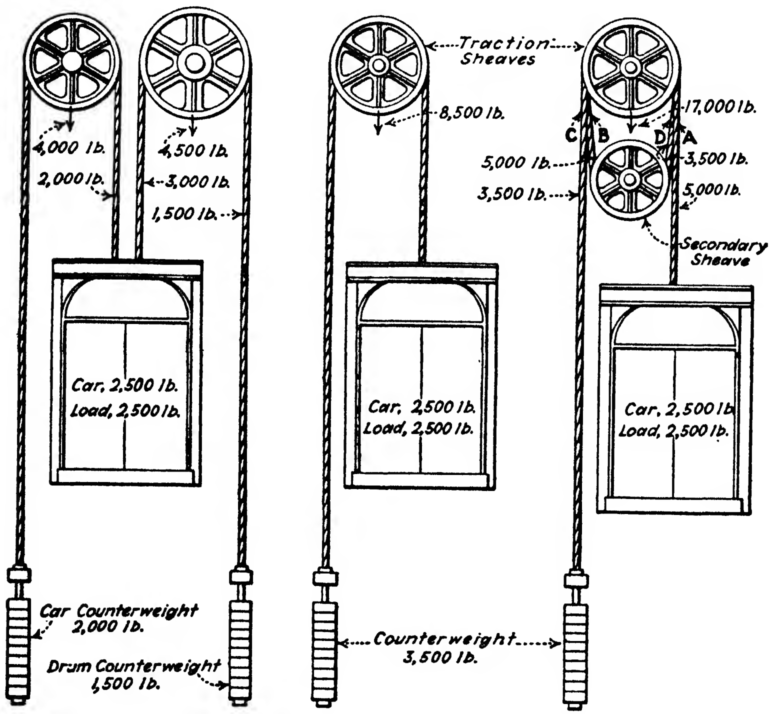


Fig. 79. Fig. 80. Fig. 81.

Figs. 79 to 81.—Loadings on overload elevator installations.

are used to provide sufficient traction between the cables and the sheave to prevent the cables from slipping. With full load in the car the maximum strain on the cables is equal to the load and the weight of the car, or in the figure, 2,500 + 2,500 = 5,000 lb. The loading on the sheave bearings is the combined weight of the car load and counterweight, or 8,500 lb. This is 4,000 lb. more than on the drum-shaft bearings of a drum-type machine installed overhead.

Full-wrap Type Traction Machines.—The machine shown in the diagram, Fig. 80, is known as a V-groove or a half-wrap type. With the full-wrap machine, Fig. 81, the cables pass from the car over the traction sheave, down around the secondary sheave, back over the traction sheave and to the counterweight. Neglecting the weight of the additional sheave and extra weight in the machine, the load on the overhead beams in Fig. 81 is the same as in Fig. 80. However, the loading on the traction-sheave

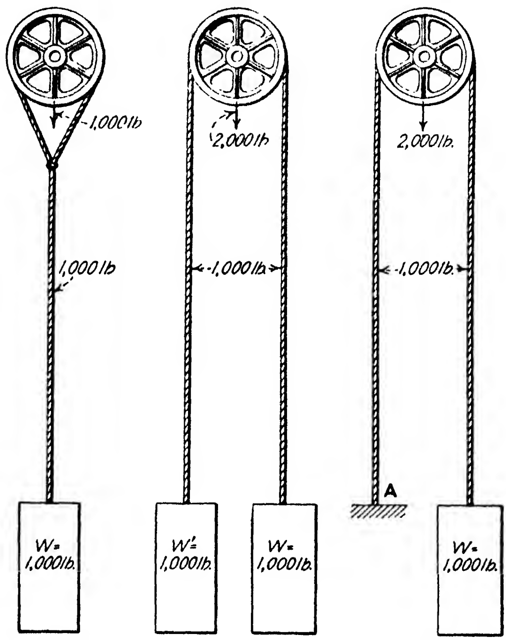


Fig. 82. Fig. 83. Fig. 84.

Figs. 82 to 84.—Explains loading of the cables in a double-wrap traction machine.

bearings has been more than doubled. In Fig. 81, cable section *A* supports the car and its load, 5,000 lb. Cable section *B* may be considered as having a tension of 5,000 lb. Cable *C* sustains the load of the counterweight, 3,500 lb., and to put this load into equilibrium, cable *D* may be considered as supporting a load of 3,500 lb. This gives double the loading on the traction sheave that exists in Fig. 80. Although the friction between the cables and the sheave will affect the loading in cables sections *B* and *D* so that it may not be exactly as shown in the figure, an equivalent loading exists. Since the loading on the traction sheave in the

double-wrap machine is double that for the single-wrap, for the same car load, the former must be constructed considerably heavier than the latter, and besides a secondary sheave is required, all of which tend to make the double-wrap machine considerably more expensive than the single-wrap type. With the double-wrap machine the friction, due to the loads on the main driving-sheave shaft and the idler-sheave shaft, is three times as great as with the single-wrap machine.

The reason for the loading on the double-wrap machine will be made clear by considering Figs. 82 to 84. If the load W is supported from the sheave in Fig. 82, then the sheave bearings must support a load of 1,000 lb. plus the weight of the sheave. This load of 1,000 lb. could be supported from the sheave by bringing the cable over the sheave and attaching a second load W' of 1,000 lb., as in Fig. 83. The cable will have the same tension in it as in Fig. 82, but the loading on the sheave's bearings will be doubled. If, instead of attaching the cable to W', it is dead ended as at A, Fig. 84, there will still be a tension of 1,000 lb. in each side of the cable, which will result in a load of 2,000 lb. on the sheave bearings, or double that in Fig. 82. What has been shown in Fig. 84, is very much the condition in Fig. 81, excepting that the counterweight and friction of the cables on the sheaves replace the dead end and the brake is applied to prevent the traction sheave from turning.

In the foregoing, to simplify the problem, all the factors that affect the loadings have not been considered, such as those forces that develop in starting and stopping, but those that have been taken account of are sufficient to indicate the advantages of one method of counterweighting or roping-up over another. Although all the various schemes of cabling up elevator machines have not been considered, the reader may work out the loading on any other arrangement by the simple process given. The weight of the car has been taken as 2,500 lb. but this will vary over wide ranges, depending upon the design. It is not uncommon for passenger cars to weigh 5,000 lb. and in some special cases probably 10,000 lb. These weights are for cars used on machines having a rating of 2,500 to 4,000 pounds.

Why Compensating Cables Are Used.[1]—Without any form of compensation the load on an elevator machine or motor will not

[1] The material on compensating cables was written by A. A. Gazda, Manager, Engineering Department, Kaestner & Hecht Company.

be constant during a run from the bottom of the hatch to the top. Starting at the first floor, Fig. 85, the motor must not only lift the difference in weight between the car and the counterweight, but in addition must raise the weight of the ropes included between the limits of travel. As the car approaches the top floor, Fig. 86,

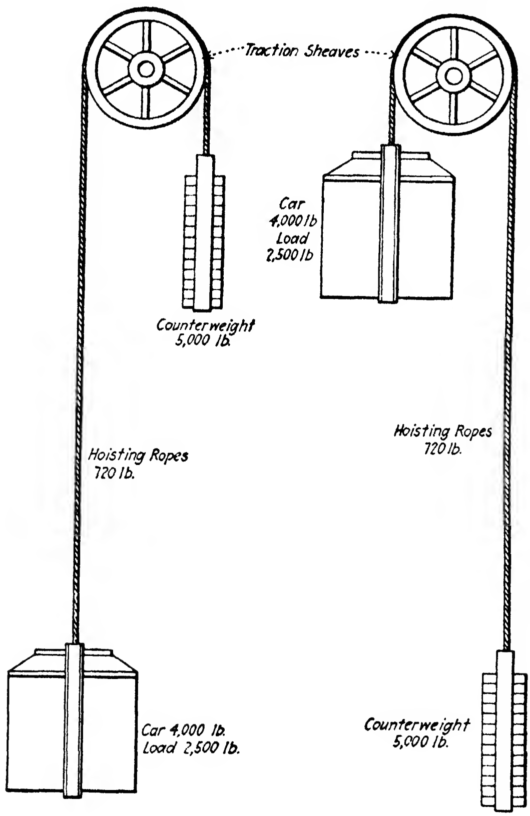


FIG. 85. FIG. 86.

FIGS. 85 and 86.—Traction-elevator machine without compensating cables.

the effective weight of the ropes is transferred to the counterweight side with the result that the load on the motor is reduced by twice the weight of the ropes. In other words, the weight of the ropes, which is added to the weight of the car and load in Fig. 85, is added to the counterweights in Fig. 86. With a rise of only a few floors this change in load is not important enough to warrant any special consideration. On the other hand, if a rise of 100 ft.

or over is involved, this factor becomes quite appreciable and means to compensate for it should be supplied.

Methods of Rope Compensation.—The simplest method of elevator-rope compensation consists of attaching one end of the compensating ropes to the under side of the car and the other end

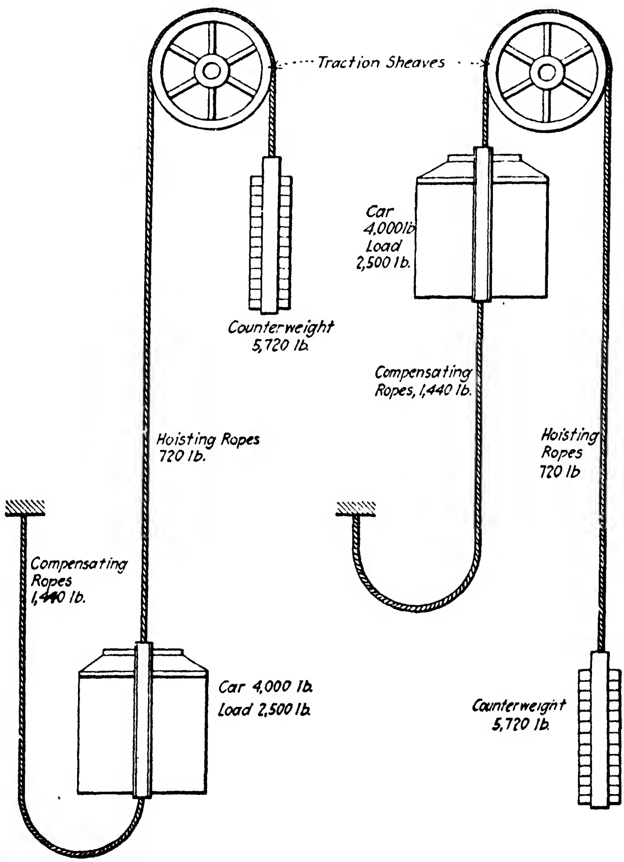


FIG. 87. FIG. 88.

FIGS. 87 and 88.—Compensating cables connected from car to center of hoistway.

at a point halfway up the shaft. This is seen in Figs. 87 and 88, which show the car at the bottom and top of the hatch respectively. A variation of this method is given in Figs. 89 and 90, where the compensating ropes are divided into two independent parts, one being attached to the car and the other to the counterweight, while the free ends of each are fixed at the middle of the

hatch. Another method consists in using one set of ropes with one end attached to the car and the other to the counterweight, as in Figs. 91 and 92. Before proceeding to the relative advantages of the three methods, a typical problem with its solution for each method will be considered.

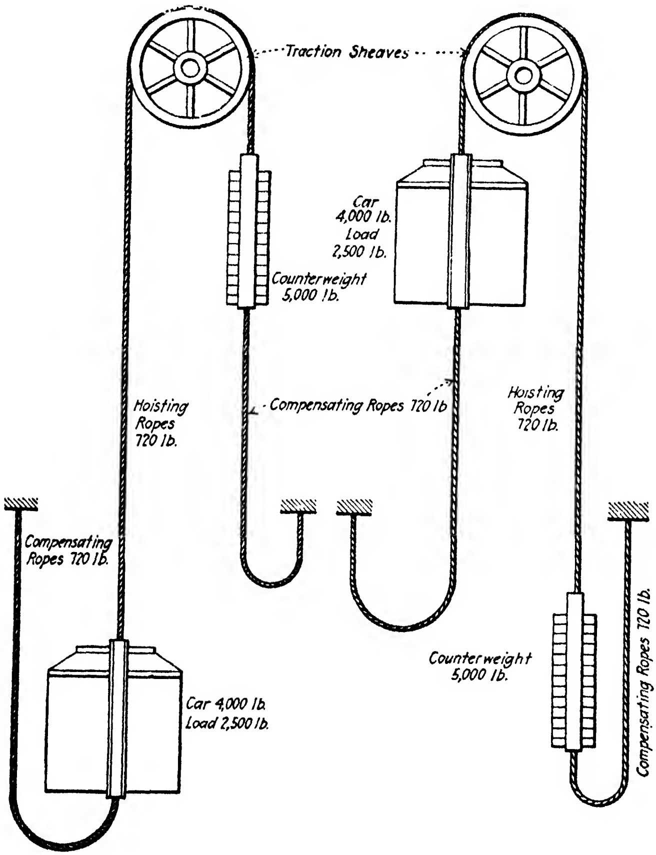


FIG. 89. FIG. 90.

FIGS. 89 and 90.—Compensating cables connected from car and counterweight to center of hoistway.

Effects of Using Compensating Cables.—Assume a load of 2,500 lb. in a car weighing 4,000 lb. The counterweight should balance the weight of the car and in addition 40 per cent of the load, giving a total of 5,000 lb. for the counterweight. A conservative design of the hoisting ropes would specify six $\frac{5}{8}$-in. steel or iron ropes. These weigh approximately 0.6 lb. per running foot,

hence, if the total travel is assumed to be 200 ft., the weight of unbalanced rope would be 720 lb. Turning to Fig. 85, it is seen that this will add a load of 720 lb. on the motor at the first landing and subtract a similar amount at the top, Fig. 86. In Fig. 85, on the car side of the sheave the load is 2,500 + 4,000 + 720 = 7,220 lb., and the load on the counterweight side 5,000 lb., or a difference of 7,220 − 5,000 = 2,220 lb. When the car is at the top of the hatchway, as in Fig. 66, the weight on the car side of the sheave is 2,500 + 4,000 = 6,500 lb., where on the counterweight side the load is 5,000 + 720 = 5,720 lb., a difference of 6,500 − 5,720 = 780 lb. Thus a total variation in load of 2,220 − 780 = 1,440 lb. will be imposed on the motor. Referring to the car and load specifications, the net load on the motor, neglecting the ropes, was 1,500 lb. when hoisting the maximum load.

Advantages and Disadvantages of the Different Methods of Compensating.—Taking up the first method of compensation, to determine the weight of the compensating ropes and the additional counterweight required to keep the load on the motor constant at 1,500 lb. when the car is fully loaded, as shown in Figs. 87 and 88. Referring to Fig. 87, it is seen that since one end of the compensating ropes is attached to a point midway up the shaft, their weight will have no effect on the motor when the car is at the bottom of the hatchway. Therefore the counterweight will be made up of three items; namely, weight of the car, 40 per cent of rated load and weight of the cables, or 4,000 + 1,000 + 720 = 5,720 lb. The weight of the car, load and cables with the car at the bottom landing is 7,220 lb., therefore the motor load is 7,220 − 5,720 = 1,500 lb.

When the car is at the top floor, the load on the car side of the sheave is the weight of the car and load and equals 6,500 lb. On the counterweight side the load is the weight of the counterweight plus the weight of the cables, or 5,720 + 720 = 6,440 lb.; consequently the load on the motor is only 6,500 − 6,440 = 60 lb. If the load were taken off the car at the top floor, the weight of the car (4,000 lb.) would be counterweighted by a weight of 6,440 lb. Therefore, for the motor to lower the car it would have to lift a load at starting of 6,440 − 4,000 = 2,440 lb. instead of 1,500 lb. if the weight of the hoisting cables were properly compensated. To maintain the load on the motor at 1,500 lb. will require attaching to the car compensating cables equal to 1,500 − 60 = 1,440 lb. In other words, the total weight of effective compensating

ropes must be equal to twice the weight of the hoisting ropes included between the limits of travel.

Take the case of two separate sets of compensating ropes attached to the car and counterweighted as shown in Figs. 89 and

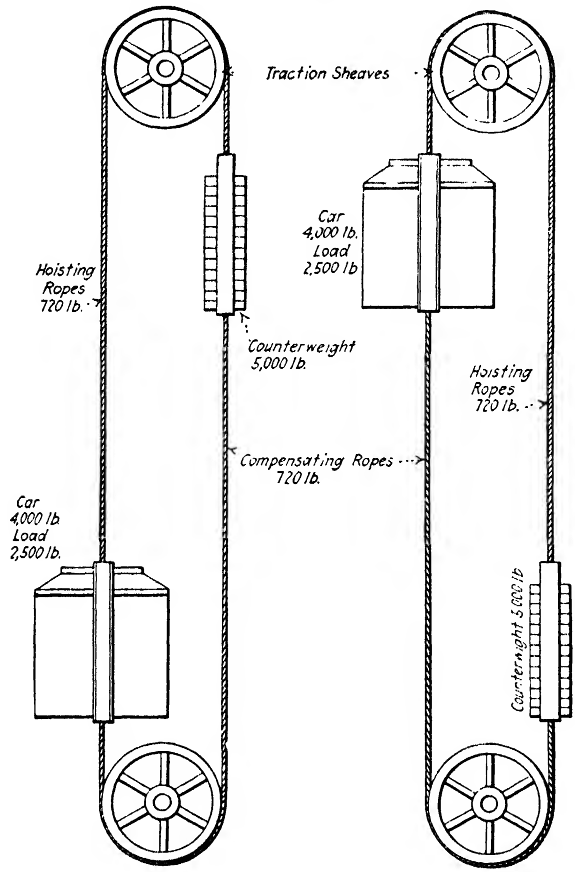


Fig. 91. Fig. 92.

Figs. 91 and 92.—Compensating cables connected from car to counterweight.

90. With the car at the bottom of the hoistway and the counterweight made equal to the weight of the car and 40 per cent of the rated load, the load on the motor when compensating ropes are not used is 7,220 − 5,000 = 2,220 lb. To reduce this load to 1,500 lb. will require compensating ropes attached to the counterweight, weighing 2,220 − 1,500 = 720 lb. When the car is at

the top landing, the weight of the hoisting cables has been transferred to the counterweight, so that the load on the car side of the sheave is 6,500 lb. and on the counterweight side 5,000 + 720 = 5,720 lb., so that without compensating ropes on the car the load on the motor would be 6,500 − 5,720 = 780 lb. If the load is to be maintained at 1,500 lb., then the car compensating rope will weigh 1,500 − 780 = 720 lb. This shows that the same weight of compensating rope has to be used in either Figs. 87 and 88 or 89 and 70, but that in the latter case the counterweight can be reduced 720 lb.

Figures 91 and 92 show a direct car-to-counterweight compensation. With this scheme the weight of the compensating cables is transferred to the counterweight when the car is at the bottom landing and to the car when the counterweight is at the bottom of the hoistway. In Fig. 91 the car, load and cables weigh 7,220 lb. and the counterweight 5,000 lb., or a difference of 7,220 − 5,000 = 2,220 lb. To reduce this difference to 1,500 lb. will require a compensating cable attached to the counterweight of 2,200 − 1,500 = 720 lb., which is the weight of the hoisting cable between the limit of travel. When the car is at the top of the hoistway, 720 lb. of the hoisting cables have been transferred to the counterweights and an equal weight of compensating cable to the car, so that the load on the motor is still 1,500 lb. This shows that the counterweight is not only at a minimum value of 5,000 lb., but the weight of compensating cables is one-half that required with either of the other two methods. A brief inspection of these three methods of hoisting-rope compensation, as shown by the foregoing discussion, will bring out the following points:

A. Method 1 requires the same weight of ropes as method 2, but additional counterweight, equal in weight to the hoisting rope, must be provided. However, an advantage of this method lies in the fact that it can be used in practically any installation, while the others may be eliminated on account of local conditions.

B. In method 2 space must be left for the second set of compensating ropes which again depends upon local conditions. The advantage of this method is that the counterweight compensating ropes assist the counterweight which may be held down to the minimum of 5,000 lb. This saving of 720 lb. weight may offset the increased cost due to dividing the cables.

C. Another factor that affects the design of the sheaves and particularly their bearings, is the total weight that will be sus-

pended. In case 1 this will be 14,380 lb., while in case 2 it will be only 12,940, which shows a reduction of 10 per cent.

D. If the compensating ropes are attached to the car and counterweight as in case 3, they will transfer their weight in the same way as the hoisting ropes do. Hence, as shown by the calculations, only one-half the weight of compensating ropes of cases 1 and 2 will be required. At the same time the counterweight is kept at 5,000 lb. while the weight on the sheaves is 12,940 as in case 2.

Thus it is seen that the third method is the best from the viewpoint of weight that must be handled. As far as accuracy of compensation throughout the travel is concerned, there is little choice between the three systems provided that they are all well designed. Sometimes it is impossible to apply the third method, as for instance if the counterweights are hung in a separate well and interference with other machines prevents the carrying across of compensating ropes. Another factor that is of importance in high-speed equipments is the elimination of noise. It is practically impossible to get noiseless operation with chains above 500 ft. per minute. For this reason wire ropes are used in the application of the third method, even though the initial cost is increased.

CHAPTER V

OVERSPEED GOVERNORS AND CAR SAFETIES[1]

Arrangement of Safeties and Guide Shoes.—In modern elevator equipment the car is carried in a sling made of channel irons, as in Fig. 93. At the top of this sling are supported the two top guide shoes *T* and at the center of the crosshead are attached the cables *C*. At the bottom end of the sling, on which the car rests, is the safety plank in which is located the safeties to prevent the car from falling in case the cables fail, and to stop the car if it attains a dangerous speed. The jaws that grip the guide rails are located at *S*, and the lower guide shoes are at *L*. The safeties are applied by a cable wound around a drum *D*. One end of the cable is attached to the drum and the other end extends up and is connected to the governor cable at *F*. The governor cable is attached to the car by a releasing carrier at *F*, and is free to move up and down with the car. In case of overspeed in the down motion the jaws on the governor grip the cable and pull it out of the releasing carrier and as the car continues downward the cable is pulled off drum *D*, which causes this drum to revolve and apply the safety jaws to the guide rails.

As has been previously explained, the car safety operates in conjunction with an overspeed governor, to bring the car to a stop by automatically clamping the car safety plank to the guide rails when an excessive speed is attained by the breaking of the hoisting cables or other reasons. Fig. 94 shows the general arrangement of the several parts incidental to a car safety. *A* represents the overspeed-governor sheave, with the cable gripping jaw *C*; *B* is the governor cable, made endless by the double-end socket *E*; *D* is what is known as the "releasing carrier," bolted to the top of the car; *J* is a weighted sheave located in the pit, *K* being the cast-iron weight or weights sliding in the guides *LL*. This device keeps a fixed tension on the

[1] M. A. Myers, Electrical Engineer, The Maintenance Co., and Howard B. Cook, Electrical Engineer, The Warner Elevator Mfg. Co., supplied a large part of the material in this chapter.

endless cable and prevents slippage on the governor sheave. *H* is the tail cable leading over a sheave or pulley *I*, to the safety-device lever, drum or tackle as the case may be, and is fastened

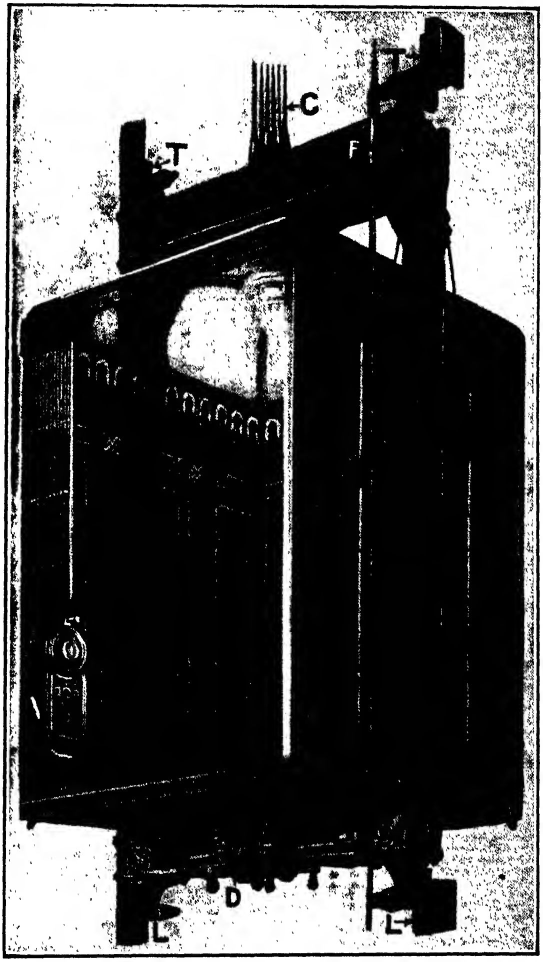


FIG. 93.—Car supported in channel-iron sling.

to the governor cable by means of an open socket *G* and a stop ball *F* clamped to the cable.

The safety governor is a device designed to bring into action one or more cable-gripping jaws to arrest the motion of the governor cable when a car reaches a predetermined overspeed, ranging

from 33 to 50 per cent above normal. The general principle does not differ from that of any other speed-controlling apparatus, the purpose being accomplished by means of weights (flyballs), arms and links held by spring tension or gravity or both against centrifugal action induced by the rotation of the balls. The roping arrangement for an A. B. See safety is shown in Fig. 95 and

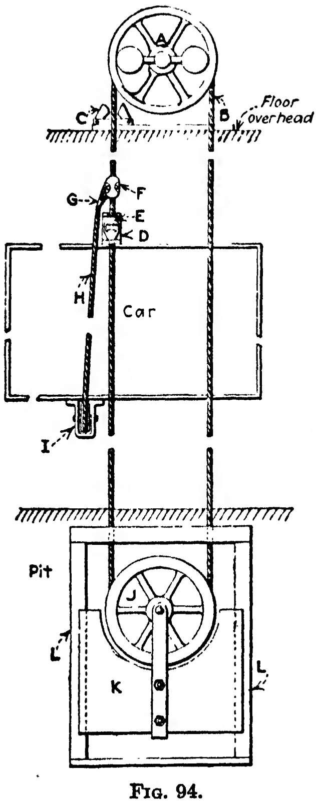


Fig. 94.

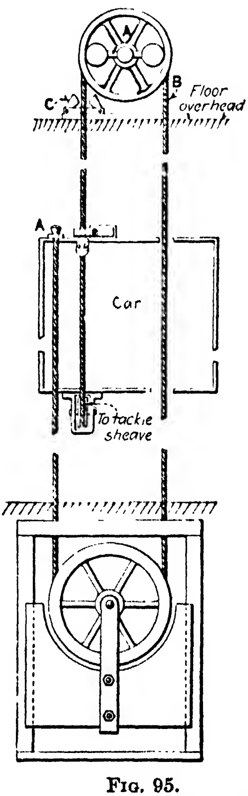


Fig. 95.

Figs. 94 and 95.—Arrangements of safety governor cables.

differs from that of Fig. 94 by having, instead of an endless cable one end of the governor cable made fast to the car, as at A, Fig. 95. The cable from the dead end passes under the weighted sheave in the pit over the governor sheave and to the tackle arrangement on the bottom of the car for setting the safeties.

Types of Governors.—Four makes of safety governors are shown in Figs. 96, 97, 98 and 99. In Fig. 96, which is a Mainte-

nance Co. governor, the sheave *A* rotates in the direction shown by the arrow when the car is in down motion. The weighted arms *W*, pivoted at *B* and *B*, are synchronized by segmental gears

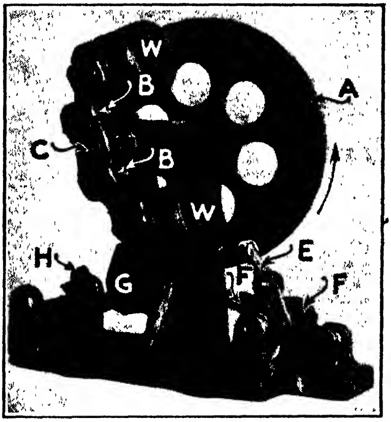


FIG. 96.—Horizontal-shaft governor.

FIG. 97.—Early type of vertical-shaft governor.

FIG. 98.—Vertical-shaft governor with fly-balls supported above end of governor shaft.

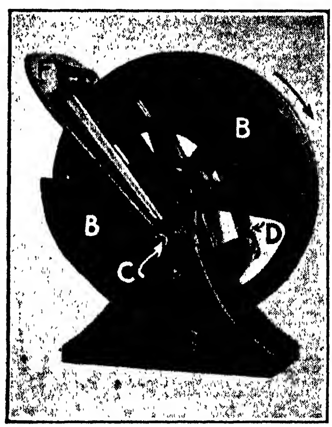


FIG. 99.—Horizontal-shaft governor with the weights mounted in the sheave.

at *C* (see Fig. 100), and are normally held from swinging apart by a tension spring *D* within the butterfly castings. The spring tension is regulated by wing-nuts on screw-eye shanks, which are sealed when finally adjusted. When the predetermined overspeed

is attained, the "balls" throw out far enough to strike the free end of the lever *E*, rocking it on its pivot and lifting the latch arm *F*. This allows the weighted arm *G* to drop, carrying with it the overweighted free arm *H*, by means of the projecting finger *J*. The jaws of *G* and *H* are eccentrically rounded and cross-

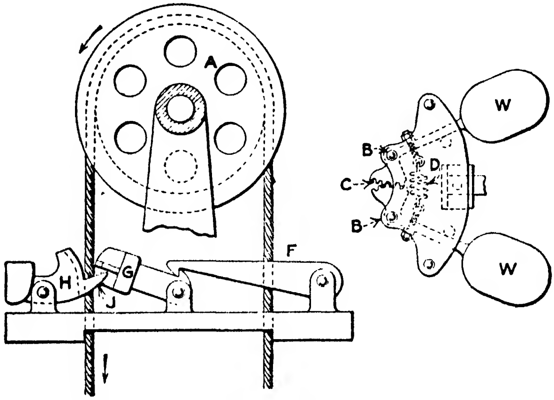
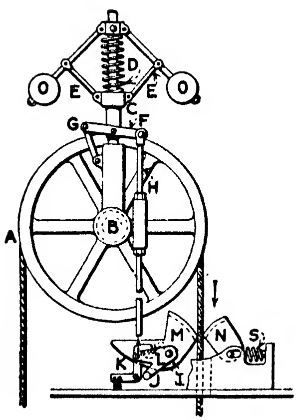
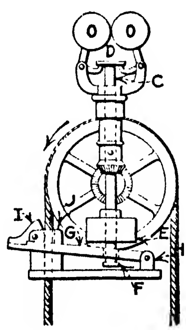


FIG. 100.—Diagram of governor, Fig. 96.





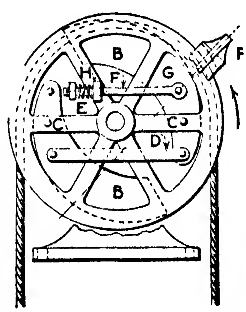


FIG. 101. FIG. 102. FIG. 103.

FIGS. 101 to 103.—Diagrams of governors Figs. 97 to 99 respectively.

corrugated, so that the instant they come in contact with the downward moving governor cable, its motion completes the clamping action, bringing the cable to a stop, thus applying the car safeties. To reset the govenor it is only necessary to raise *G* until it latches.

In the Otis governor, Figs. 97 and 101, rotation is transmitted from the sheave *A* to the governor balls *O*, through bevel gears at *B*. As the balls throw outward, the sleeve *C* is drawn upward against the tension of spiral spring *D*, through the medium of the connecting links *E* and *E* (See Fig. 101). The sleeve carries with it the divided lever *F* pivoted at *G*. The upward motion is transmitted through the adjustable connecting rod *H* to the actuating lever *I*, a projecting finger *J* in turn pushing back

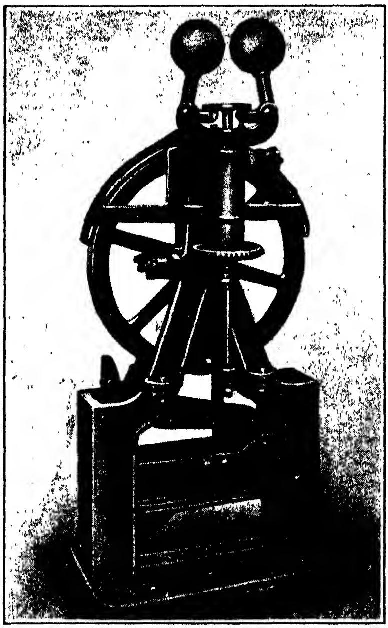


Fig. 104.—Improved type of governor operating on the same principle as Fig. 98.

the latch *K* that holds the jaw casting *M* in position by means of the projecting lug *L*. Once unlatched, *M* drops and the companion jaw *N*, synchronized with *M* by segmental gears, drops with it and contact is established with the cable in downward motion, which completes the clamping action. Jaw *N* is held in slotted holes in the frame against the pressure of spring *S*, which gives a certain amount of flexibility to the jaw to ease the gripping action on the cable.

In the Gurney governor, Figs. 98 and 102, the balls *O* are rotated by gears as on the Otis governor. When the flyballs throw out-

ward, the through rod *C* weighted by *E*, is lifted by means of the disk *D*. The tripping lever *G* pivoted at *H*, is then pulled upward by the collar F, its outer end rotating the gripping eccentric *I* on its pivot, clamping the governor rope between its jaw and the fixed jaw *J*, thus causing application of the car safeties. Figure 104 shows an improved type of a Gurney governor.

Figures 99 and 103 show a type of governor in which two flat curved weights *B* and *B* are pivoted, a short distance from their

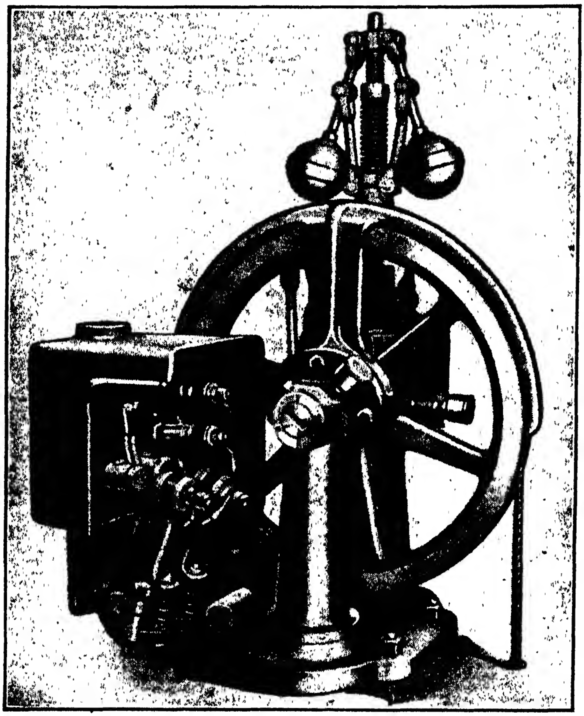


Fig. 105.—Vertical-shaft governor with control switch.

small ends, to the sheave spokes at *C* and *C*. The throw-out motion of the weights is synchronized by the cross-connecting rod *D*, Fig. 103 and the regulation is obtained by the compression spring *E* on the shank of the eye-bolt *F*, pivoted to one of the weights at *G*. The shank passes loosely through a projecting lug *H* on one of the sheave spokes and has an adjustment which is sealed when finally regulated. When the predetermined over-speed is reached, the weights throw out sufficiently to strike the

heavy U-shaped casting F, carrying it upward toward the vertical center line. As this casting is pivoted eccentrically at C, Fig. 99, its extended jaw draws more deeply into the groove of the sheave as it approaches the vertical position. The motion of the cable completes the clamping action as soon as contact is established.

On high speed machines many of the governors actuate switches that work in conjunction with the controller as is discussed in the chapters on controllers. Figure 105 shows an Otis governor with a double-contact switch.

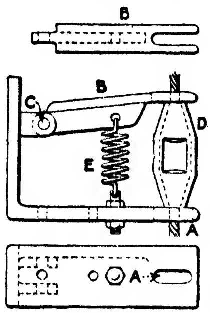
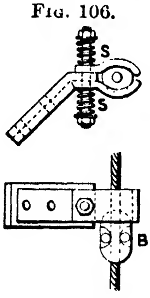


FIG. 106.



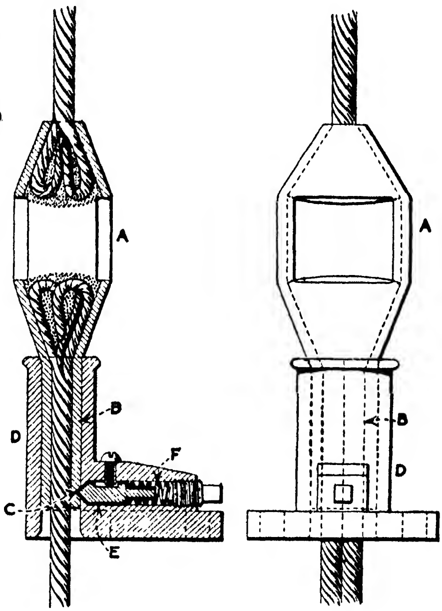


FIG. 107. FIG. 108.

FIGS. 107 to 108.—Types of governor-cable releasing carriers.

Motion is imparted to the governor by the releasing carrier, which is bolted to the top of the car or to the crosshead. This carrier overhangs the edge of the car, and holds in a flexible grasp that leg of the cable which passes through the gripping jaws, Figs. 94 and 95. The carrier has a spring arrangement that releases the governor rope when the motion of the latter is checked by the "setting" of the governor. The only connection then remaining between the governor rope and the car is through the tail rope H, Fig. 94, leading to the safety device proper, which is then actuated by the downward motion of the car.

Figure 106 shows a simple releasing carrier. The governor cable passes through an elongated hole *A* in the cast-iron base and is held by the claw finger *B*, pivoted at *C*, clamping the double-end connector *D* with the aid of spring *E*. When the motion of the governor cable is arrested by the car's downward motion, finger *B* is moved upward on its pivot and the cable slips out of the slot. Another type of releasing carrier, shown in Fig. 108, makes use of a modified form of a double-end connector *A* with an extended flattened shank *B* provided with a notch *C*. This is held within the body of the cast-iron base *D* by means of a pointed trigger *E* under pressure of the spiral spring *F*. Both the governor cable *G* and the tailrope *H* are socketed in the lower basket of the modified connector as shown on the right. An A. B. See releasing carrier is shown in Fig. 107, in which the stop ball *B* is held beneath two curved jaws normally held closed by two spiral springs *S*. When the governor sets, the releasing carrier jaws are spread by the extra strain and the stop ball slips through.

Requirements for Good Governor Operation.—It might seem that the overspeed governor on an elevator is a rather unimportant part of the equipment. It performs no service in normal operation and it may not be called upon to act during the life of the elevator. If the other safety devices, such as the car switch, emergency switch, mechanical brakes or dynamic brake, should fail to prevent excess speed or if the cables should break, then the governor would be called upon, first to open the potential-switch magnet-coil circuit and then to operate the governor rope grip.

It is evident that reliability is of first importance in the operation of the governor. The design must be such that wear or rust will not prevent operation at a critical time. It must be sensitive to overspeed yet it must be stable so that accidental operation will not occur. The design should be such that normal speed will cause a slight movement of the weights. This will indicate that the weights are free to move, and this is also useful in observing whether the elevator is operating at the proper speed.

Adjusting Governor Switches.—Where governor switches are used it is customary to adjust the governor so that an excess speed of 20 per cent will operate the switch. The opening of this switch will release the potential switch and cause the machine to stop by the cutting off of the current to the motor and the application of the magnetically operated brakes. If the car continues to increase in speed, the governor will operate the rope

grip at 40 per cent overspeed. These percentages are arbitrary and should be reduced if it is possible to do so without causing the governor to act on account of the normal variations in speed.

Tension in Governor Rope to Apply Safeties.—The governor rope grip must stop the governor cable so that further descent of the car will cause the cable to be pulled loose from the releasing carrier on the car and the unwinding of the safety cable from the safety drum under the car. This action will engage the safety device. The continued descent of the car will continually increase the pressure of the safety jaws against the guides, and it is possible that this force might become so great that some part of the safety device would be overstrained before the car would be brought to rest. To obviate this danger, the governor rope grip is provided with a spring or other device that will permit the governor rope to slip after a sufficient force has been applied to stop the car, but before any part of the safety mechanism is overstrained. The rope must in any case be sufficiently strong to pull the governor cable loose from the releasing carrier on the car. The tension necessary to slip the cable varies with the design of the safety device and the capacity of the elevator. It is seldom less than 300 or more than 1,200 pounds.

Vertical-shaft versus Horizontal-shaft Governors.—The earliest governors used on electric elevators were of the vertical shaft flyball type, such as shown in Fig. 97. The design was probably borrowed from the steam-engine practice of that day. The horizontal-shaft governor, one type of which is shown in Fig. 96, is coming into wide use on elevators in present-day practice and this type has several advantages, chief of which is simplicity. The vertical-shaft type must be geared, usually with bevel gears, and wear often causes the gears to become noisy.

There is, practically, but one moving part in the horizontal-shaft type, and with proper design all the desirable characteristics of the vertical-shaft type can be attained. The geared governor has some advantages on slow-speed elevators where, as will be shown later, the centrifugal forces available on the direct-drive type may not be sufficient to overcome the friction resistance, but many of the governors in use on slow-speed elevators are of the direct type, while many in use on high-speed elevators are of the geared type. The governor is generally operated by a ½-in. iron or steel cable running on a sheave that is usually 16 in. in diameter for high-speed service.

At low speeds the centrifugal force tending to move the weights W is very small, but increases with the square of the speed. The force in pounds can be obtained from the equation $F = \frac{WV^2}{gR}$, where W is the weight in pounds of the governor balls, V the velocity of the center of gravity of the weights in feet per second, R the radius or distance in feet from the center of rotation to the center of gravity of the balls, and g the acceleration of gravity, or 32.2.

Assume an elevator speed of 600 ft. per min. If the governor sheave is 16 in. in diameter, it will have a speed of 143 revolutions per minute, or 2.4 revolutions per second. If the distance of the center of gravity of the balls from the center of rotation is 6 in., or 0.5 ft., the effective velocity of the weights at 2.4 revolutions per second will be $2.4 \times 3.1416 = 7.5$ ft. If the combined weights of the balls is 8 lb., the centrifugal force will be $= \frac{8 \times (7.5)^2}{32.2 \times 0.5} = 28$ lb. At a car speed of 300 ft. per min. the force would be 7 lb., at 150 ft. per min. 1.75 lb., and at 75 ft. per min. 7 oz. It is apparent that at low speeds the centrifugal force would scarcely be sufficient to overcome friction and insure dependable operation. Reduction of the sheave diameter would increase the speed of rotation and thereby increase the centrifugal force available. This reduction would be justified because a slow-speed elevator does not travel many miles in a day and the rope life would be long even though the relative life would be shortened.

With the vertical-shaft type the governor balls are in static balance in all positions; in the horizontal-shaft type the individual weights are only in static balance in two positions. It is necessary to connect the two weights together with a suitable linkage so that the unbalance of one weight will compensate the unbalance of the other and thereby keep the weights in static balance in all positions.

Some governors of the horizontal-shaft type are made without a connecting link between the weights, but the spring tension must be sufficient to overcome the effect of gravity in addition to the centrifugal force at normal speed. Such governors require a high speed for their operation. It is difficult to adjust some types of governors on account of friction, because the connecting link between the two weights is attached close to the supporting pin. Under these conditions the pressure on the pins at the ends of the

link is several times as great as the weight of the balls. Moreover, this force is also impressed on the pins that support the balls. In some cases the spring pressure is carried through the connecting link and tends to increase the pressure on the weight pins. It is possible to arrange the connecting link so that the unbalance of the individual weights does not impose a heavy pressure on the supporting pins, and when the spring is connected directly between the two weights, the friction that would, under other conditions, oppose the movement due to centrifugal force, is reduced to a minimum and closer regulation can be attained.

When the governor balls move out due to centrifugal force, the radius of the center of gravity increases and the centrifugal force increases because of the greater velocity due to the greater radius. If the spring pressure does not increase at a greater rate than the centrifugal force, the weights will move out to the limit of action without any increase in the speed of rotation. Under these conditions the rope grip will be operated together with the governor switch whenever the critical speed is exceeded. To stabilize the governor and cause the weights to move out gradually with the increase in the speed of rotation, it is necessary to so proportion the spring that its reaction will increase more rapidly than the centrifugal force.

Inertia is another factor that must not be ignored in the design of a governor. Steam engineers who are familiar with the principle of the "Rites" inertia governor know the effects produced when a load is suddenly applied to a steam engine equipped with this device.

When the governor weights are supported on pins that have their axes parallel to the governor shaft, a sudden start produces a tangential force that will tend to assist the centrifugal force and cause the governor to act more quickly or at a lower speed than would be the case if it were accelerated slowly. This action might seem to be valuable in causing the governor to act more quickly in case of a falling car. Sudden starts are, however, common in normal operation, and in governors of this type used on slow-speed elevators, the effect of inertia due to normal starts may be several times as much as the centrifugal force at normal speed. Under these conditions it would be necessary to tighten the governor spring so that a great excess in speed would be necessary for operation if the overspeed were attained at a low rate of acceleration.

Rates of acceleration equal to one-fourth of gravity are not uncommon in elevator service, and a sudden start of this value would produce a force equal to one-fourth the weight of the governor balls. In most designs of this type only a part of this force would tend to cause the governor to act, depending upon the radius of action of the center gravity of the weight and the distance of the supporting pin from the center of rotation. The effect of inertia is entirely neutralized in the vertical-shaft governor because the supporting pins are set at right angles to the axis of rotation. This is also true of the horizontal-shaft governor when the weights are supported in the same relative manner.

Inertia-type Governors.—On modern high-speed elevators, operating up to 1,400 ft. per min., it has been found desirable to use combination speed and inertia-type governors. Normally

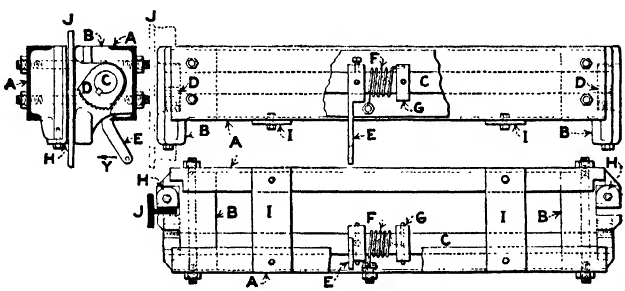


FIG. 109.—Instantaneous safety with single gripping eccentrics.

the governor functions as a flyball type. If for any reason the car accelerates at a high rate, as when falling, the inertia element comes into effect and sets the safeties on the car, when it is moving at a comparatively slow speed. The inertia element is a weight that at normal speed accelerates with the governor. At high rates of acceleration the movement of the weight lags behind that of the governor and causes the safeties to be applied on the car. Such governors are used on the high-speed cars in the Rockefeller Center main building.

Single Eccentric Safeties.—In modern elevators the safety is located beneath the car. Safeties may be of the instantaneous or clamp type for speeds under 200 ft. per min. or gradual or compression type for car speeds over 200 ft. per min. A single eccentric safety of the former class, for light duty cars, is shown in Fig. 109. *A* and *A* are the channel irons and are bolted to the safety heads *B* and *B* by through bolts as shown. The safety heads are heavy castings and are provided with renewable brass wearing plates, or gibs *H*, converting them into combination

safety heads and guide shoes. *C* is the rocker shaft, on either end of which are keyed the gripping eccentrics *D* and *D*. *E* is the tripping lever, *F* a torsion spring for holding the rocker in position and for bringing it back to position when the safety is released, one end of the spring being fast to the collar *G*, pinned to the rocker shaft, and the other end bolted to the channel-iron frame. *I* and *I* are bumper plates and *J* the steel guide rails.

When the governor sets from overspeed and locks the governor cable so that it cannot travel with the car, it is pulled out of the

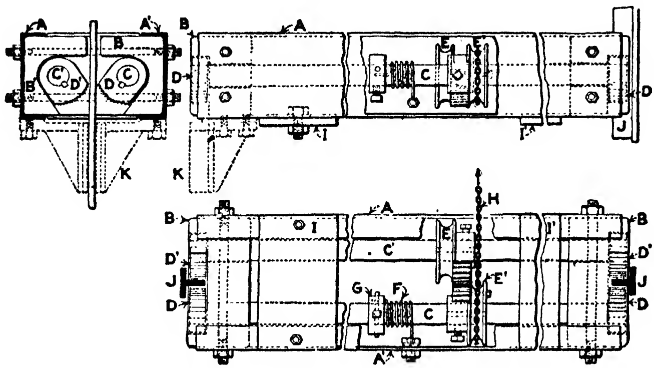


FIG. 110.—Instantaneous safety with double gripping eccentrics.

releasing carrier, as previously described. The tail cable, being fast to the releasing carrier, also becomes stationary and the falling car causes lever *E*, to which the tail rope is fastened, to be jerked in the direction of the arrow *Y*. The gripping eccentrics are thus rocked upward, and the instant their corrugated edges come in contact with the guide rails, they are carried the remaining distance by the motion of the car itself, relieving the tail rope of any further duty. The gibs *H* are pulled against the guide rails and the eccentric locks the car.

Heavy-duty Double-eccentric Safeties.—Figure 110 shows a heavy-duty double-eccentric instantaneous safety. It has two rocker shafts *C* and *C′* with eccentrics *D* and *D′*, instead of one. The motions of the two shafts are synchronized by the keyed segmental-geared sheaves *E* and *E′*. A tripping chain *H* working in the groove of one of the sheaves is utilized to set the safeties instead of the tripping lever of Fig. 109. *K* and *K* are guide shoes bolted to the safety plank. The action is identical with that of Fig. 109, the guide rails being gripped by the double eccentrics instead of between a single eccentric and gib.

To release the car after either of the foregoing types of safeties has set, it is only necessary to wind the hoisting cables back on

the drum, taking up the slack slowly and carefully. Then raise the car by holding the brake open and using a spanner wrench or bar, usually provided for the purpose, on the brake coupling to turn the worm shaft. The lifting may also be done by working the controller by hand, first blocking open the accelerating device, but this method is liable to be abrupt, imposing a severe strain on the cables. As the car lifts, the eccentrics will roll downward until free of the guide rails, when they will be snapped in place by the torsion spring. After the governor gripping jaws have been released, the governor cable is restored to its anchorage in the releasing carrier. The reason for the setting of the safety, if other than the parting of the hoisting cables, must be ferreted out and the cause removed. The guide rails should also be examined to determine if roughening, displacement or other damage was done.

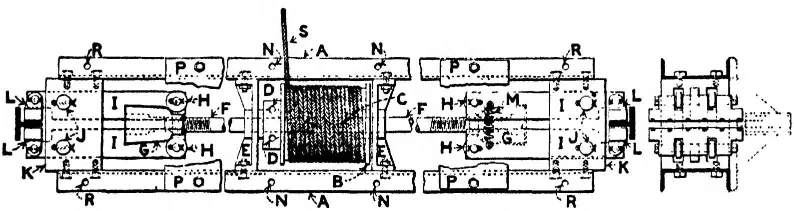


FIG. 111.—Parts and assembly of compression-type safety.

Compression-type Safeties.—A Maintenance Company gradual or compression-type safety is shown in Fig. 111. *A* and *A* are channel irons bolted to the safety heads *K* and *K*. *B* is the safety drum, keyed at *C* to the drawbars *F*, and provided with a cylindrical extension with holes *D* and *D* for releasing purposes. *E* and *E* are bearing brackets. . The drawbars *F* are threaded at either end, right and left hand, the ends screwing into heavy wedges *G* and *G*. The four parts *I* are the heavy main safety levers pivoted at *J* by heavy pins and provided at the inner ends with rollers *H*. The bottom safety levers and resetting spring are removed at the left for clearness. Pinned to the outer or short ends of the main levers are the gripping dogs *L*, with cross-grooved gripping surfaces. A fiber roller is held against the tail rope wound on the safety drum, by four spiral springs, and its function is to prevent the drum from unwinding by vibration, to prevent snarling of the tail rope when the safety has operated and to aid in releasing the safety. *P* and *P* are the bumper plates and *R* holes for bolting on the guide shoes. The action of this safety is as follows:

When the governor cables, and consequently the tail rope, are locked, the dropping car unwinds the cable off the safety drum. This action causes the drawbars to turn and screw into wedges *G*, drawing the latter toward each other their tapered faces entering between the rollers *H*. The safety levers are therefore spread apart at their inner ends and, rocking on their pivots *J*, force the gripping dogs *L* toward each other against the guide rails. The

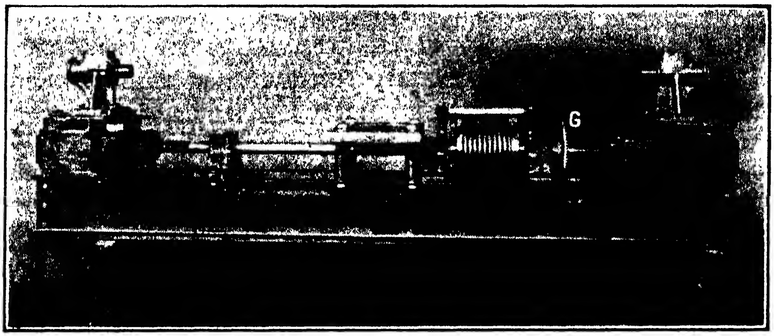


Fig. 112.—Assembly of compression-type safety.

pressure increases until the increasing friction between the dogs and the rails overcomes the car momentum and the car comes to a stop in about 6 to 8 ft. after the setting of the governor.

To release the car, the car-hoisting cables are replaced on the machine drum and the slack taken up. The governor gripping jaws are released and latched. A small opening in the floor of the car is uncovered and a short bar used in the holes *D* and *D* to

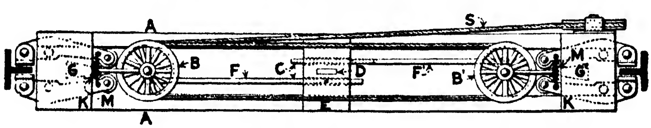


Fig. 113.—A. B. see compression-type safety.

wind the safety drum. When the wedges are thus screwed back to their original positions, the springs *M* restore the safety levers pulling the gripping dogs away from the guide rails. The safety, Fig. 112, operates on the same principle as the one, Fig. 111, but is released by a tool with a gear on it that engages gear *G* in the figure. The tool is used through a hole in the floor of the car.

An A. B. See safety shown in Fig. 113 has an action similar to the one just described, with the exception that a rope-and-tackle

scheme is used instead of the drum and drawbar. The tail rope S is wound about a series of tackle sheaves B and B', each set consisting of about five sheaves. When the tail rope is held by the action of the governor, the falling car causes the two sets of sheaves to be drawn toward each other and along with them wedge G and G', after which the action is precisely as that described in the previous paragraph. F and F' are resetting rods fast at the outer end to the tackle-sheave yokes, the inner or free ends sliding in grooves in the casting E. The free ends are provided with notches C on the upper surface. To release this safety, after the hoisting ropes are wound upon the drum and taking the weight of the car, the tail rope is pulled down to gain slack and the weighted governor sheave in the pit is blocked up to ease the operation. A special flat bar wrench is inserted through an oblong opening in the floor of the car directly over E, the end of the bar projecting through the rectangular opening D in E. When the bar is rocked, attachments on either side of it engage the teeth C, forcing the bars, and therefore the tackle sheaves, in opposite directions. Repetition of this operation forces the wedges from between the rollers and the tension springs M restore the main safety levers to their off position, thus freeing the car.

Flexible Guide-clamp Safeties.—Figure 114 shows an Otis Elevator Company safety known as the "flexible guide-clamp type." It consists of two heavy jaws A and B pivoted at C. Jaw B is provided with a wedge D and a loose cylindrical serrated roller E, normally held in position at the lower or thin end of the wedge as shown. When the governor sets and the lever F is rocked upward by the action of the tail rope on the rocker shaft G, the roller is carried upward until it is brought into contact with the guide rail. The motion of the car then continues the upward progress of the roller between the rail and the inclined face of the wedge. Jaw A is pulled against the rail, and as the roller continues upward the heavy adjustable spring H is compressed until the pressure between A and the roller against the rail grows sufficient to overcome the momentum of the car, bringing it to a stop. This safety is released similarly to the instantaneous safeties previously described. A flat rod I extending to the top of the car is arranged to pull up lever F with the roller in case of the breaking of the hoisting cables, without waiting for the governor to act.

Two new safeties, designed to meet the exacting requirements of the American Standards Association and the New York City

codes, are installed on each elevator, one under the car platform and one on the counterweight, on the high-speed elevators in Rockefeller Center. It is usual practice on elevators of ordinary speeds to install an oil buffer in the pit to stop the car should it overtravel the bottom terminal. For a car at 1,400 f.p.m. this requires a buffer so long in stroke that its design becomes difficult and its installation sometimes impossible. A special terminal-stopping device therefore was developed, together with a new inertia-type governor, previously described, and a terminal-stop control, which will automatically set the car safety should the

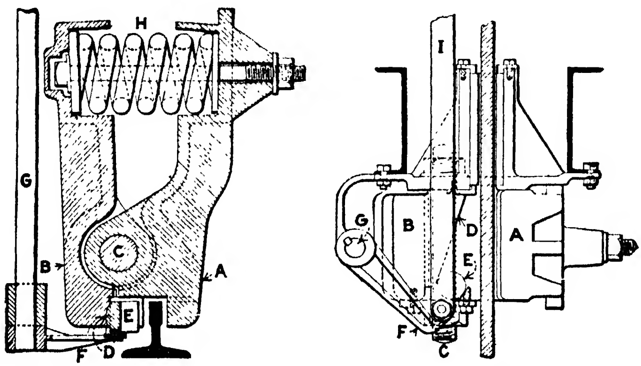


FIG. 114.—Flexible guide-clamp type safety.

elevator approach the terminal at a speed in excess of a predetermined value. This enables the use of normal short-stroke buffers in the pits.

On the double-deck cars in the City Service building, clamp-type car safeties are mounted at both the top and bottom of the car-safety frame, Fig. 48. These safeties are set to give a positive emergency stop under full load. To assure a smooth, gradual stop with only a light load in the compartments, the mono-mass safety device is used. This apparatus is mounted on the compensating sheave in the pit. Its function, without going into the discussion of the characteristics of the law of gravity and the property of moving masses that would be necessary for a detailed description, is to so tie together the moving parts of the elevator system—the cars, hoist ropes, counterweight, and compensating ropes—that they operate as a unit mass. The result is a more uniform emergency stop regardless of load in the elevator cars.

There are many other types of car safeties, but most all of them are on the same general principles as described in the foregoing.

CHAPTER VI

DIRECT-CURRENT BRAKES, THEIR CARE AND ADJUSTMENT

Mechanically Operated Brakes.—On an elevator machine, the brake is one of the most important parts of the equipment, for upon its proper functioning depends not only the safety but also the satisfactory operation of the machine. If the brake fails to function, control of the car may be lost by the operator, with serious results. If the brake is applied too harshly, the car will be stopped with an unpleasant jerk to the passengers and the equipment will be strained unnecessarily. When the brake is not applied with sufficient force, the car will be difficult to control and make the floor landings.

Elevator brakes have been made in about as many forms as there are types and makes of machines, so that about all that can be done in any article is to indicate a few of the different types and how they operate and are adjusted. Figure 115 is a diagram of one of the earlier type of elevator machine mechanically operated brakes. The two cast-iron shoes S and S' are hinged at H and attach to lever L at A. Lever L is attached to a second lever B that is raised and lowered by a cam C on the shipper wheel, the latter not being shown. When the shipper wheel is turned to either running position by the operator pulling the hand rope in the car, the left-hand end of lever B is raised and with it lever L. This allows shoe S to drop away from the brake wheel until it is brought to rest on stop D, after which shoe S' is lifted by a further upward movement of lever L. The application of the brake is the reverse of this process, and the force with which the brake is applied is controlled by the position of the weight W.

In general it may be said that a brake should be adjusted so that the shoes just clear the wheel. However, where the brake is operated mechanically, it may be necessary to adjust it to open considerably more than this so that it will not be applied before the power is cut out of the motor. In adjusting the brake, Fig. 115, screw D is put in a position that will let the brake shoe S drop

clear of the wheel and screw E is then adjusted so that shoe S' will clear the wheel by the same amount as shoe S when the operating mechanism is in the full-on position. After this has been done, the operating mechanism should then be pulled slowly to the off position and a check made on the controller to see that the brake cannot be applied hard while the motor is still connected to the line. If such a condition exists, it will be necessary to give both brake shoes more clearance from the wheel. After the brake shoes have been properly adjusted, the weight W is moved to a position that will stop the car within the desired distance.

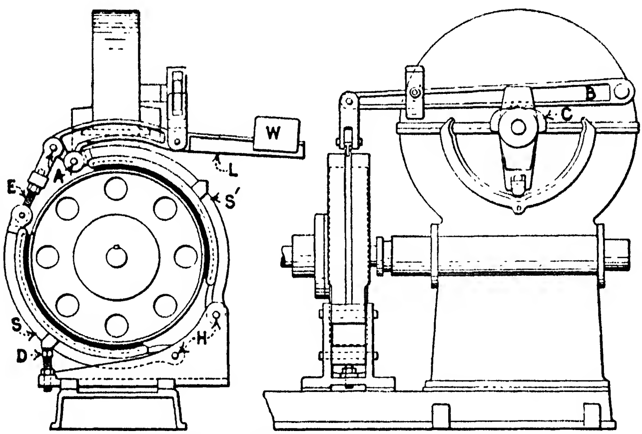


Fig. 115.—Mechanically operated brake.

On some of the older types of machines the starting resistance could be cut into circuit before the power was cut out of the motor. In such a case, if the brake was applied before the motor was disconnected from the line, it would be possible to stop the motor with the resistance in series and connected to the power supply, in which case the starting resistance will be overheated. In one case in mind, the operator left the elevator stopped this way when he left the building on Saturday noon, and when he returned Monday morning found everything combustible on the motor and controller burned up, even to the wood terminal blocks. Probably the only thing that saved the building was that the equipment was installed in a fireproof room. Such occurrences were not uncommon with some of the old types of mechanically operated machines. If the brake can be applied before the

power is cut out of the motor, the fuses are likely to be blown, if the resistance is not cut into the motor circuit. If the fuses do not blow, breaking the heavy current on the controller contacts will cause serious burning on these parts. Improper brake adjustment, especially on some of the older types of machine, was not infrequently the cause of considerable controller trouble.

Instead of using cast-iron shoes lined with leather as in Fig. 115, some of the older types of brakes consisted of a steel band lined with leather. The two ends of the band were connected to the brake lever in a manner similar to that shown in the figure, and the center of the band was made fast so that the brake would be opened from both ends. One of the difficulties with a band brake is to get it to clear the wheel at all points when released, due in a large part to the band not bending to a true circle about the wheel.

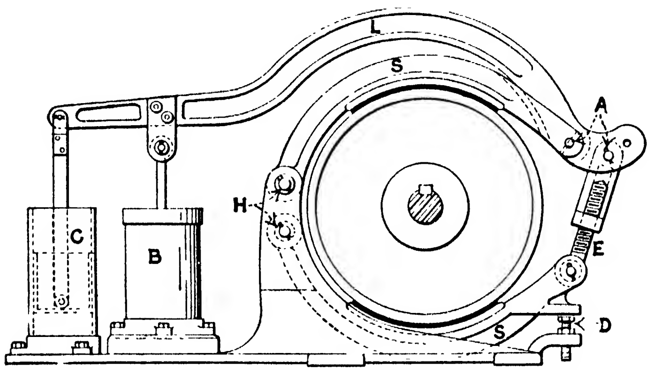


FIG. 116.—Modification of the brake, Fig. 109, arranged for electrical operation.

Electrically Operated Brakes.—A somewhat similar type of brake to that in Fig. 115 is shown in Fig. 116, except that it is solenoid operated. The shoes adjusting screws and lever are lettered as in Fig. 115. The lever is brought back over the brake wheel and is connected to a solenoid *B* and an air dash pot *C*.

The solenoid is energized from contacts on the controller. Energizing of the coil causes it to pull up its core and lift the lever, thus clearing the brake shoes from the wheel. The force with which the brake is applied is controlled by the dashpot. After the brake shoes have been adjusted so that both just clear the wheel when solenoid *B* has pulled up its core, the dashpot should be adjusted to allow the brake to be applied easily. The correct adjustment of the dashpot can be determined by starting

and stopping the car. This type of brake, if the shoes are given too much clearance from the wheel, may allow the lever to drop so far that the dashpot will bottom before the brake is applied, in which case it will be difficult to stop the car. It may also be possible that the core in the solenoid will drop down so far that the coil cannot develop pull sufficient to release the brake. For this reason care should be exercised to get the brake properly adjusted. With a magnet-operated brake, the contacts on the controller, that make and break the coil circuit, must be kept adjusted so that they will always break the circuit when the power is cut out of the motor and make the circuit when the motor is connected.

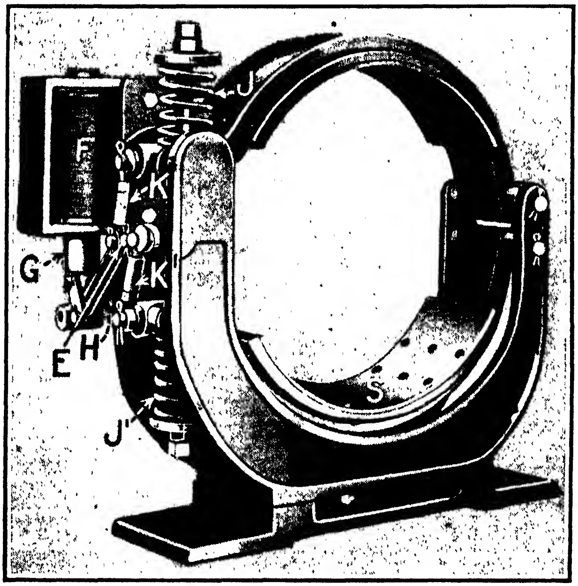


Fig. 117.—Modern type of electrically operated brake.

Equalizing the Clearance between the Two Shoes.—On the two brakes discussed the lever has no fixed fulcrum, therefore the brake shoes cannot be adjusted so that one shoe is applied harder than the other, although one shoe may be released or applied ahead of the other. With the type of brake shown in Fig. 117, the brake lever *H* has a fixed fulcrum pin *E*, about which the lever moves up and down. In this brake the leather-lined shoes *S* are applied with springs *J* instead of a weight. Each shoe is attached to the lever *H* by turnbuckles *K* and *K'* and the long

arm of the lever is attached to the core G of the solenoid F. When coil F is energized, it pulls up its core and the brake lever. In so doing turnbuckle K is pushed up and with it the top brake shoe against the tension of spring J. Likewise, turnbuckle K' and the bottom brake shoe are pushed down against the tension of the spring J', thus lifting the shoes clear of the wheel. When the coil circuit is opened, the core and lever is released and the brake shoes are applied by the springs, assisted by the weight of the solenoid core on the end of the lever.

In adjusting the type of brake, Fig. 117, it is essential that both shoes clear the wheel equally so that they will be applied with equal force to the wheel. If turnbuckle K' is made considerably longer than K, it may be possible to have the top shoe applied hard on the wheel and the bottom shoes not touching. After the top shoe has set on the wheel turnbuckle K would then hold the lower shoe away from the wheel. It is easy enough to adjust the shoe to the same clearance, simply by blocking the end of the lever up into the release position and then turning the turnbuckles to obtain the desired clearance for each shoe.

Equal clearance of the brake shoes does not necessarily give the best stopping of the car, although it is the best starting point in the final adjustment. The type of brake, amount of counterweight and average loading of the car, and dynamic-braking action of the motor all have an influence. With the type of brake in Fig. 117, where one shoe can be applied harder than the other, it may be found that the car will stop more quickly in one direction than in the other. In extreme cases, the car may stop with a decided jar in one direction and slide in the other. This is an indication that one brake shoe is being applied harder than the other; which one can be determined by inspection or a little experimenting. First try setting one shoe a little closer to the wheel and operate the car again. If this adjustment improves the setting, it is known that the adjustment is being made in the proper direction. If the stopping is not improved or is made worse, the wrong shoe is being adjusted. After the brake has been once properly adjusted, any adjustment for wear should be made equal on each shoe by marking the turnbuckles and turn each an equal amount.

Magnet Acts Directly on the Shoes.—In Figs. 118 and 119 is shown a Cutler-Hammer brake for use on direct-current elevators and cranes. The arrangement of parts is such that the operating

magnet acts directly on the brake shoes. Coil C is in a movable housing H, which is hinged at B and is attached to the shoe on the opposite side of the brake wheel by the rod R. The other brake shoe is connected directly to armature A of the magnet. When the coil is energized, the armature is attracted to the magnet, but its motion is limited by the screw D, after which the magnet is pulled to the armature and releases the shoe on the opposite side of the wheel. When the coil circuit is opened, the brake is applied by the spring S, located in the center of the magnet, and forces the armature and magnet apart.

As all parts of the brake are acted upon by the same force, each shoe will be applied with equal effort to the wheel. One of the

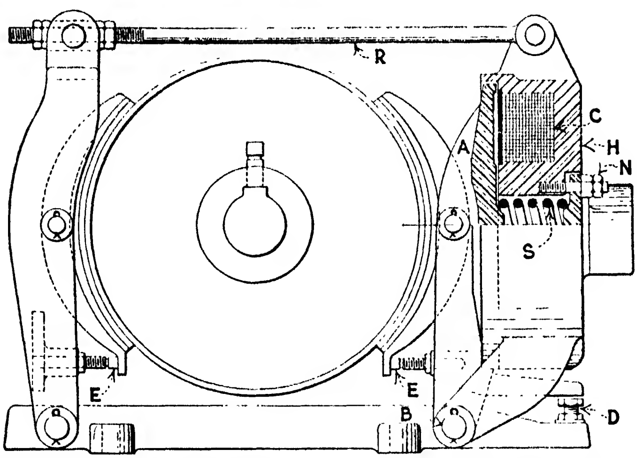


Fig. 118.—Shows general arrangement of the parts of the brake, Fig. 119.

features of the design is the absence of toggles, bell cranks or levers to transmit the motion of the magnet's core to the brake shoes. Another feature is the small amount of motion of the magnet's armature, which is from $\frac{1}{16}$ to $\frac{1}{8}$ in. to lift the brake shoes clear of the wheel. This short movement of the magnet's armature results in an almost instantaneous application or release of the brake and also tends to prevent any bouncing or hammer blow action of the brake.

In adjusting the brake, the intensity of the force with which the shoes are applied to the wheels is obtained by taking up on or releasing the nuts N, Figs. 118 and 119, which act directly on the heavy spiral spring at the center of the magnet. The amount of

clearance between the brake shoes and the wheel is controlled by adjusting the length of rod *R*, by the nuts on its left hand end. Lengthening the rod increases the clearance and shortening has the opposite effect. This adjustment should be made such that the shoes will just clear the wheel when the brake is released. Screws *E* are used to adjust the shoes so that their top ends will not fall over and ride on the wheel when the brake is released. Adjusting screw *D* up or down, as the case may require, equalizes the clearance of the two shoes on the wheel.

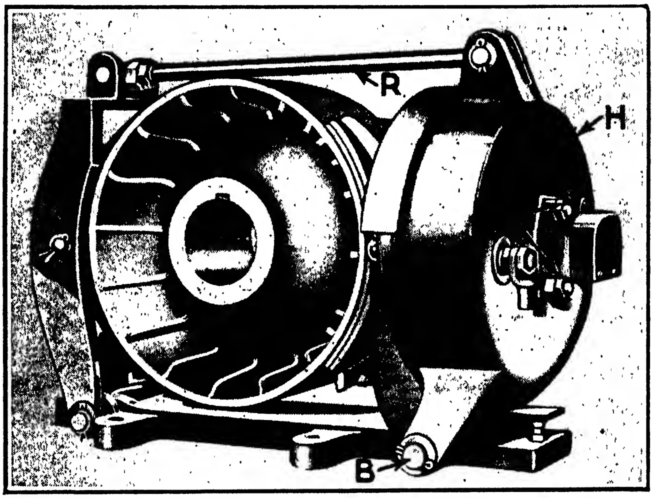


Fig. 119.—Brake magnet acts directly on the brake shoes.

Brakes with Double-core Magnets.—The brake shown in Fig. 120 is one type used by the Otis Elevator Co. and is one that has a small movement of the various parts during operation. A single magnet coil *E* with a double core *D* and *D'* is used for releasing the brake, and the shoes are applied to the wheel with spiral springs *S*. The brake levers are fulcrumed at *F* and the shoes are attached at *A*. When the coil *E* is energized, it pulls the two cores *D* and *D'* together and in doing so lifts the shoes off the brake wheel. The shoes being hinged at their middle and lifted away from the wheel at the horizontal diameter by the levers, they are lifted an equal distance from the wheel at all points, which is not true of some type of brakes that have the shoes hinged at one end. The lifting of the shoes equally at all points on their

periphery allows for a minimum movement when releasing and applying the brake.

The movement of cores *D* is adjusted on the screws *E* until, when the inner ends of the cores are in contact, the brake shoes just clear the wheel. Then screws *H* are adjusted to insure equal movement of each brake shoe. These are adjusted so that they will be about touching the stops at *H′* when the brake is released and the shoes are an equal distance from the wheel. The amount

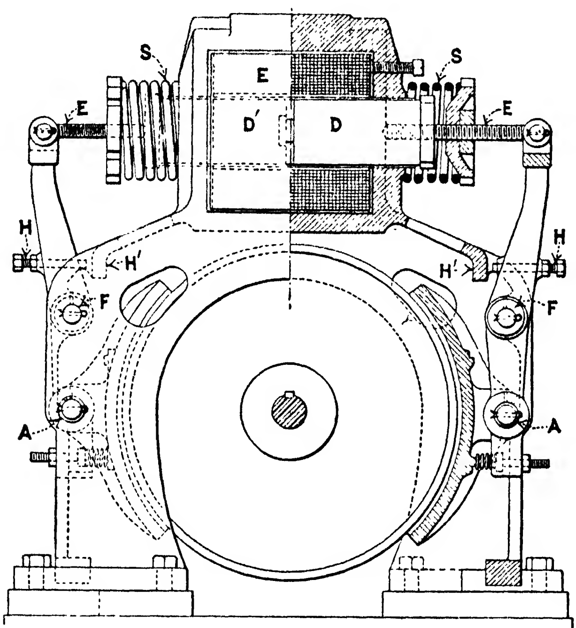


Fig. 120.—Brake for use on one of the earlier types of high-speed elevators.

of pressure that the brake applies to the wheel is obtained by adjusting the spiral springs *S*. This tension should be such as to stop the car without any undue jar to the passengers. In this type of brake one shoe is applied independently of the other; therefore the springs should have equal tension. This can be determined with sufficient accuracy by measuring the length of each spring, and they should be of equal length.

As previously mentioned, adjustments are made by screwing the stems *E* in and out of the cores *D* and *D′*, so that when the cores are pulled together the brake shoes will be lifted clear of the

wheel. As the lining of the shoes wear, the stems *E* should be backed out of cores *D* and *D'* periodically to maintain this adjustment. If such an adjustment is retained until the lining of the shoes is worn to where it must be renewed, when the lining is put into the shoes, it will probably be found that with the old adjustment, the cores *D* and *D'* will touch when the brake shoes are in contact with the wheel. To correct this condition the stems should be screwed into the cores to separate the latter enough to give

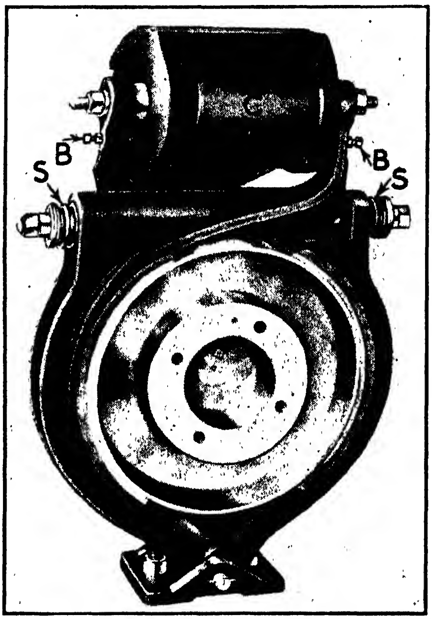


Fig. 121.—Brake coil mounted between the two top ends of the brake shoes.

sufficient movement to lift the shoes clear of the wheel. In adjusting the brake, care must be exercised not to separate the cores too far, or the coil may not develop sufficient pull to lift the shoes from the wheel.

On the brake, Fig. 121, built by the Neenan Elevator Corporation, the left-hand shoe is connected to the right-hand core in coil *C*, and the right-hand shoe is connected to the left-hand core. With this arrangement, when the cores are pulled together by the coil, the brake is released by a direct pull on the shoes. This method of connecting up the brake shoes to the magnet cores

allows mounting the brake shoes directly on the machine frame. The magnet cores are adjusted so that when they are together the shoes will be just clear of the wheel, and the necessary pressure on the wheel is obtained by the tension springs *S*. As the rod on which the springs are supported is continuous, any adjustment made on one spring affects both shoes alike. Bolts *B* are used to obtain equal clearance for each shoe as was explained in Fig. 120.

Mechanically and Electrically Operated Brakes.—The brake Fig. 122 is mechanically operated, but is applied electrically in case of failure of the power supply. The brake lever *L* is con-

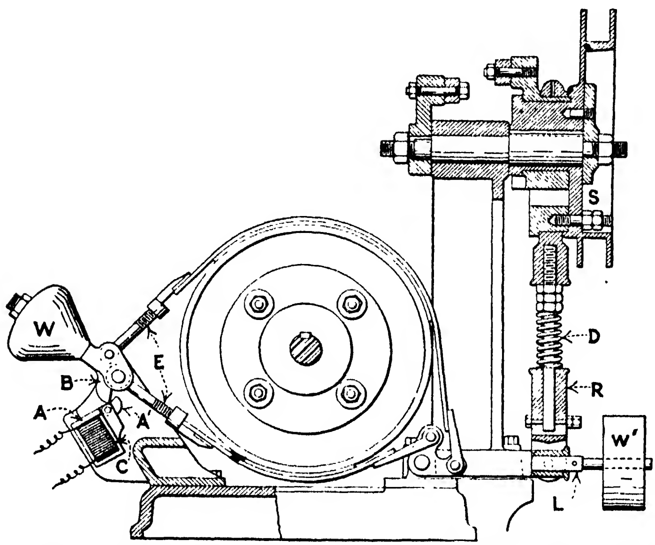


Fig. 122.—Combination mechanically and electrically operated brake.

nected to the shipper wheel *S* by the adjustable rod *R*. Coil *C* is connected directly across the power line. As long as the line is alive, coil *C* will be energized and will hold armature *A* in the position shown. The extension *A′* is part of armature *A*, and *B* is an extension of the lever carrying weight *W*. From this arrangement it can be seen that as long as armature *A* is held to the coil, weight *W* will be held in the position shown.

Under normal operation the brake is released and applied by the movement of skipper wheel *S* raising and lowering lever *L*. The tension with which the brake is applied is controlled by spring *D*, as well as by the position of weight *W′* and the adjust-

ment of the screws *E*. If the power fails, coils *C* will release armature *A* and weight *W* will fall and apply the brake, and it cannot be released by the mechanical operating mechanism until weight *W* is raised and held in its off position. This prevents the operator from leaving the brake released on the machine with the power off the motor. On this type of brake, one brake shoe can be applied harder than the other if not properly adjusted, therefore careful attention should be given to this feature when making adjustments.

Care of Brakes.—Before a brake can be expected to work properly the surface of its linings must be in good condition. There are three common materials used to line brake shoes—namely, leather, asbestos and wood—and the preference for these materials is about in the order named. The surface of the linings should be kept free of oil and dirt. Oil may work out along the worm shaft from the gear case and get on the brake wheel. When this occurs, the shoes should be removed and the oil and dirt scraped off with glass or washed off with gasoline. Applications of fullers earth may be made to absorb the oil, after which it can be scraped to leave the surface of the lining clean. Leather brake linings sometimes become dry and hard, in which case they should be treated with a good leather dressing or neatsfoot oil.

In adjusting a brake the electrical features cannot be overlooked. In most modern direct-current elevator controllers, the armature of the motor after being disconnected from the line is connected through a resistance. This causes the motor to act as a generator and offer a retarding effect on the motion of the machine, or, as it is called, dynamic braking. To insure satisfactory stopping the resistance of the circuit must be a correct value, but this is generally properly adjusted when the installation is put into service and requires no further attention except in case of short-circuits or open-circuit in the dynamic-braking resistance. On high-speed elevators, connection schemes are used in the brake circuit to accommodate the braking action to the different speed and loadings of the car at the time of stopping.

Brakes on High-speed Elevators.—Conditions under which an elevator must be stopped are many, ranging between the extremes of full load in up motion and full load going down. In the remainder of this chapter, attention is given to the brake on an Otis high-speed direct-traction machine of the type shown in Fig. 119. In order to obtain a clear conception of the circuits of a

high-speed elevator controller it is advisable for the reader to first study Chapter X, before considering the brake adjustment.

In order to give a clear conception of the load in either the up or the down motion, it will be assumed that the elevator is counterweighted for 40 per cent of its rated load; this is the usual amount of counterweighting, but subject to 5 or 6 per cent variation, depending on the service to which the elevator is applied. Counterweighting for 40 per cent of capacity load indicates that the counterweight will weigh as much as the elevator car plus 40 per cent of capacity load. Assume the case where the following weights are involved: Elevator car, 3000 lb.; capacity load, 2,500 lb.; counterweight, 3,000 + 40 per cent of 2,500 = 4,000 lb.

With full load in the car going up, the motor must lift an unbalanced load of (3,000 + 2,500) − 4,000 = 1,500 lb. In stopping, gravity assists by virtue of the unbalanced load of 1,500 lb. With full load in the car going down, the unbalanced load manifests itself by driving the motor as a generator, and in stopping, gravity opposes the braking action with a pull on the hoisting ropes equivalent to the unbalanced load of 1,500 pounds.

The difference between the two extreme conditions in stopping is a positive action of 1,500 lb. in the first case and a negative action of 1,500 lb. in the second case. This is equivalent to a difference of 3,000 lb. pull on the hoisting ropes between stopping on the up and stopping on the down direction with full load.

From the foregoing it must not be understood that the unbalanced load alone must be considered in the stopping, but every pound of the equipment in synchronous motion with the machine tends to keep the equipment in motion when the power is cut off. This energy, which is the energy that must be dissipated in stopping the elevator, is the energy required to start the equipment and build up or accelerate the elevator to full speed. The unbalanced load assists or opposes the stopping, depending on whether the motor is lifting or lowering the unbalanced load.

The energy of a moving mass is proportional to its weight times the square of its velocity, therefore the required braking action increases as the weight and the square of the speed. Twice the mass requires twice the braking action; double the speed requires four times the braking power. Neglecting friction of the moving parts, there are three distinct factors that determine the stopping of an elevator:

1. The force of gravity due to the unbalanced load which assists or opposes stopping, as described in the foregoing; in the case of a balanced load there is no action due to gravity.

2. The motor acting as a generator when power is cut off, the kinetic energy of the equipment serving as the driving power. Current is delivered to suitable resistance, called a bypass resistance, mounted on the controller where energy is dissipated as heat as follows: The shunt-field winding is connected across the line, thus providing for a field at all times. The armature is connected to a bypass resistance which is cut in and gradually short-circuited as the machine comes to rest (see Fig. 123). A voltage is induced in the armature conductors rotating in the

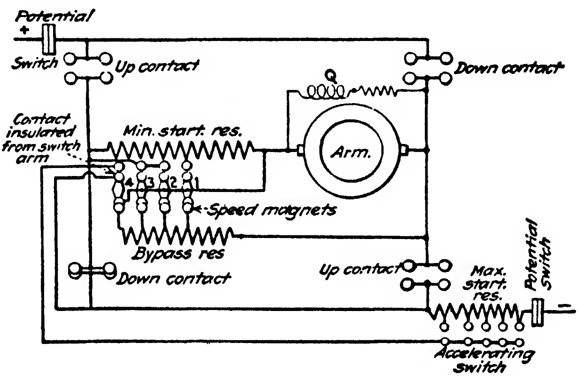


FIG. 123.—Diagram of motor circuits.

field. This voltage causes a current to flow through the bypass resistance, where it is dissipated as heat. The energy thus dissipated is a measure of the average voltage, average current and time in which the elevator is stopped.

By short-circuiting the armature, a very abrupt and unpleasant stop may be obtained owing to the fact that the amount of current flowing through the armature circuit is determined by the low resistance of the armature conductors, brushes and leads only. This current will be extremely high, the average voltage remaining practically the same (decreasing from the same maximum to zero); the time of stopping must be less since the same energy is dissipated as in the previous case. Generally speaking, the bypass resistance across the armature must be of such value that most of the stopping is provided by the current in the armature circuit

without obtaining an abrupt stop, the brake shoes serving as an auxiliary only. However, the brake shoes must provide sufficient holding power to hold the elevator at rest under all conditions of load.

Various loads change the condition under which the elevator must be stopped. This variable condition is taken care of automatically to a considerable extent by the motor. When the car switch is centered to bring the elevator to a stop, the voltage available in the armature winding immediately delivers current to the bypass resistance. The value of this current is determined by the induced voltage or counter-electromotive force of the armature winding and the resistance of the armature circuit.

Consider a negative load which is the case when lowering a load heavier than the counterweights. Under this condition the motor does not take current from the line, but in most cases delivers current back to the line, the amount of current depending on the amount of unbalanced load which is the driving power for the motor acting as a generator. When the unbalanced load is not sufficient to overcome the losses in the machine, the motor will draw current from the line. The induced voltage available in the armature in the former case will be equivalent to line voltage E plus the voltage drop IR in the armature winding and expressed in the form of an equation is, counter-electromotive force $= E + IR$. The available voltage when the motor is lifting an unbalanced load, armature drawing current from the line, is equal to line voltage minus the IR drop in the armature, or counter-electromotive force $= E - IR$.

In the first case gravity tends to oppose stopping and in the second case assists stopping. When the car is on the down motion a greater stopping effect is obtained from the motor because of the greater counter-electromotive force available, while on the up motion a lesser counter-electromotive force is obtained, resulting in a reduced stopping effect of the motor. In this way the stopping effect of the motor automatically opposes the action of gravity.

3. The friction of the brake shoes upon the brake pulley is the third action that is utilized in the stopping of an elevator.

The counterweighting and value of the bypass resistance are fixed when an installation is completed, and for this reason the brake holds the greatest attention. In making repairs or relining brake shoes, the brake is dismantled, and upon completion of such

repairs the brake must be readjusted. The principle upon which the brake derives its braking power will now be considered.

Braking power is obtained by reason of the friction of the brake linings upon the brake pulley and expressed in the form of an equation for a given speed, is,

$$\textit{Friction} = \textit{pressure} \times \textit{coefficient of friction}$$

where friction is expressed in pounds pull on the brake pulley, pressure is that due to the springs, and coefficient of friction is a constant determined by materials in contact, temperature and speed of brake pulley.

The brake linings in most general use are leather or multibestos, the latter having a more constant coefficient of friction with different conditions of temperature and speed. Another preference for the multibestos linings is in the case of the brake obtaining undue slide, squeaking or abrupt stopping caused by oil or gummy substance on the brake linings. With the multibestos linings it is a simple matter to saturate the linings with gasoline and burn them clean. With leather linings it is more difficult to clean without extreme care.

In order to have a good brake action the surface of the pulley and brake linings should be kept perfectly clean, as the introduction of any foreign substance will change the value of the friction, thereby either causing a quicker stop or increasing the distance the elevator slides.

The next point in good brake operation is to maintain the minimum clearance of the brake shoes from the pulley when the brake is lifted, and the spring tension on the brake shoes should be equalized, otherwise the brake shoe with the greater tension will press against that side of the brake with the greatest force, tending to spring the shaft on which the pulley is mounted. Failing to give due consideration to these two points in brake adjustment is the principal cause of most brake troubles.

Figure 124 shows the electrical circuits involved with the brake winding. The resistances used are, *BR*, brake resistance; *ABR*, auxiliary brake resistance; *PBR*, parallel brake resistance; *PBR'*, auxiliary parallel brake resistance. The purpose of the *ABR* resistance is to reduce the current in the brake winding after it has lifted the brake shoes clear of the pulley. This reduces subsequent heating in the brake magnet, at the same time providing for quick release of the brake when starting. This resistance is used

on brakes with single windings that are connected across the line when the elevator is started. With another type of brake a compound winding is used. A heavy or series winding is connected in series with the armature and short-circuited out after the brake has lifted, serving the same purpose as the *ABR* resistance. The *PBR* and *PBR′* resistances are for utilizing the energy stored up in the brake electromagnet to provide for a slow application of the brake shoes to the pulley.

A flywheel in motion tends to keep turning after the power is cut off; in the same manner an electromagnet tends to remain energized when the current is cut off, provided there is a circuit through which the current can flow when the line current is interrupted. The *PBR* and *PBR′* resistances provide this circuit. This current prevents the magnetic field from decreasing at a rapid rate, thus slowing up the application of the brake shoes. The

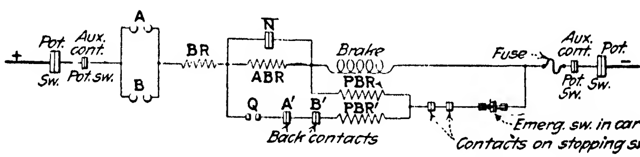


FIG. 124.—Diagram of brake circuits.

electrical circuits of the brake are such as to provide three different applications of the brake. At the terminal landings it is desired to provide a more positive braking action than at the intermediate landings. The object of this would be to prevent excessive run-by, and second, because of the automatic slow down, the brake application may be harder at the terminal stops than at the intermediate landings. The application of the brake at the intermediate floors must be more gradual, for running at high speed, should the brake be applied immediately upon stopping, not only would there be an unpleasant and abrupt stopping action, but the brake linings would have a short life due to excessive wear. The third application of the brake is in inching to floors where it is desired to level the elevator platform with the landing. In this case it is necessary to provide for a quick action. In inching up to floors it requires close adjustment of brake shoes to the pulley, for should the brake shoes lift too great a distance, the period of time required for the shoes to move through the clearance would permit the load to overhaul. By overhauling is

meant the action of the unbalanced load moving the elevator between the time power is cut off the motor and the time the brake shoes are applied to the pulley. The adjustment of the brake to obtain the best operation will now be considered:

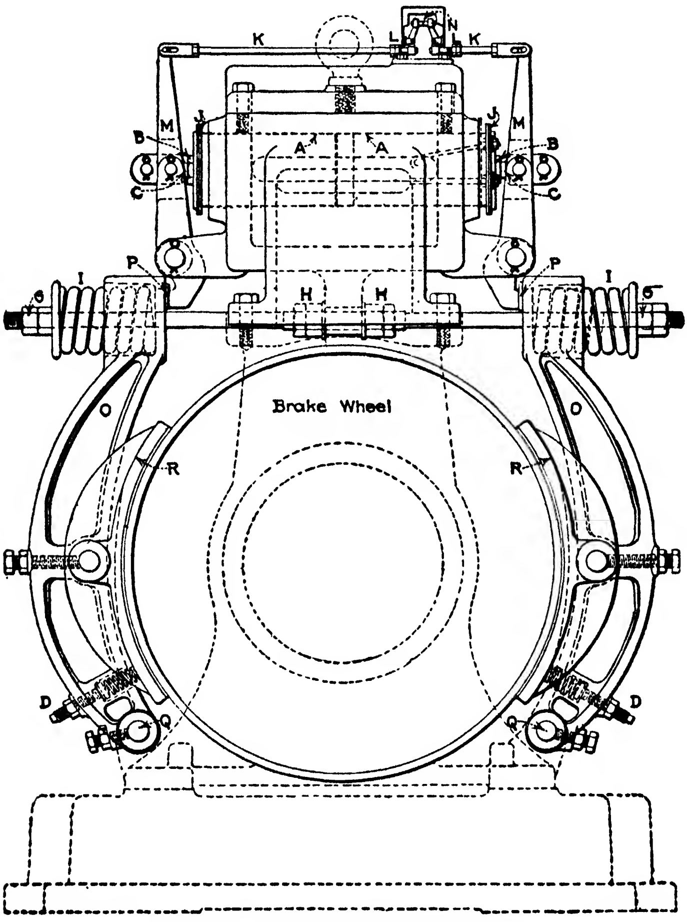


Fig. 125.—Diagram of brake equipment.

Adjusting Brakes on High-speed Elevators.—1. Brake shoes and pulley must be perfectly clean.

2. Adjust magnet cores *AA*, Fig. 125, to obtain the minimum lift by unlocking nuts *BB* and moving cores *AA* either in or out as desired. Magnet cores *AA* are drilled and tapped, and are moved in or out by turning the cores on the threaded studs *CC*.

Equalize the lift at the top and bottom of each shoe by screwing in or out studs *DD* to obtain the required results.

3. Adjust nuts *LL* on the braking switch *N* so that when the brake magnet has pulled in, the contacts are opened the minimum distance required to break the arc.

4. Tighten up nuts *GG* to obtain the spring tension necessary to give the desired stop with full load. The nuts *HH* should be slacked off while doing this and then pulled up equally to insure equalizing the tension on the springs *II*.

5. The *ABR* resistance, Fig. 124, should be of such value that by increasing it an appreciable amount, the current flowing through the brake winding will not be sufficient to hold the brake released against the pressure of the springs. This value of *ABR* provides for the magnetic field set up by the current in the brake

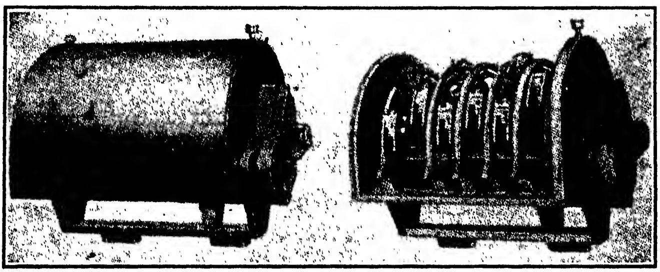


FIG. 126.—Automatic stopping switch, which is located on top of car.

winding to be of sufficient value to hold against the springs with a small decrease in voltage.

6. Leather washers *JJ* keep the cores *AA* from butting and should be of sufficient thickness to provide a positive release of the cores when power is cut off. The principle involved is the introduction of an air gap which will weaken the residual magnetism to such an extent that it will not prevent the magnet cores from releasing. At the same time these leather washers provide for a softer blow when the magnet cores pull in instead of striking metal to metal when operating.

Referring to Fig. 124, the manner in which the various circuits in connection with the brake operate will be considered. The *BR* resistance is permanently connected when used, for the purpose of reducing the current in the brake circuit to the smallest value necessary for the operation of the brake. The *ABR* resistance is

short-circuited by a contact mounted on top of the brake-magnet frame and actuated by rods *KK*, Fig. 125, adjustment being made by threaded nuts *LL*. When the brake magnet is energized, the magnet cores *AA*, attached to lever arms *MM*, pull in and open contact *N*, introducing resistance *ABR* into the brake circuit, thereby reducing the current, lever arms *MM* at the same time striking lever arms *OO* at the point *P* causing the latter to move about point *Q*. This motion of lever arms *OO* causes the brake shoes *RR* to clear the brake pulley. As mentioned before, the contact *N* should be so adjusted as to open the minimum distance required to break the arc.

Resistance *PBR* is of comparatively high value, while *PBR'* is of low value. *PBR* resistance is in series with two contacts which are mounted on shaft limit switches in the case of earlier-type machines, while in the latter type these contacts are mounted in the stopping switch, Fig. 126, mounted on the crossbeam of the car sling. *PBR'* is in series with a back contact on each direction switch and also with a contact which is operated by a magnet *Q* (see Fig. 123) connected across the armature. This latter magnet operates only when the motor has come up to a definite speed or to that speed where voltage across the armature is of sufficient value to operate the magnet. *PBR'*, together with these contacts in series with it, parallel the *PBR* resistance.

The operation of the brake is as follows: When the car-switch control handle is moved for either direction of travel, the respective direction switch will operate. Auxiliary contacts mounted on the direction switches close the brake circuits. These contacts are indicated at *A* on up-direction and *B* on down-direction switch, Fig. 124. *A'* and *B'* are back contacts on the up and down direction switches respectively. These contacts are made when the direction switches are released, and *A'* opens when the up-direction switch closes, and *B'* opens when the down-direction switch pulls in; therefore, when either direction switch pulls in, the *PBR'* circuit is opened. At this time current flows through the brake magnet coil, and the *ABR* resistance is shorted out by contact *N* mounted on the brake. Resistance *PBR*, paralleling the brake, takes a very small amount of current from the line, but serves no purpose at this time.

When the brake magnet lifts, contact *N* is opened, which cuts in the *ABR* resistance, reducing the current in the brake winding and thereby decreasing the heat losses in the brake circuit.

After the motor builds up to about 50 per cent of normal speed, magnet coil *Q*, Fig. 123, pulls in and closes contact *Q*, Fig. 124. When stopping, magnet *Q* will not release until the motor has come down to a slow speed, therefore when the direction switch releases, the *PBR'* resistance circuit is closed until low speed is obtained. Under this condition, at the first application of the brake at the intermediate landings its application is easy for the reason that the *PBR'* circuit is closed. When the motor has slowed down to the point that magnet *Q* releases and opens its contact *Q*, because of the high resistance of the *PBR* resistance, the brake application is harder for the slower speed. The brake application is first easy and then increases as the elevator comes to a stop. At the terminal landings, when the contacts mounted on the stopping or limit switches as the case may be, are opened, all parallel brake-resistance circuits are opened, preventing any circulation of current through the brake coil when the elevator is brought to a stop. This provides for a hard application of the brake shoes.

When inching to floors, magnet *Q* will not close contact *Q* for the reason that the motor does not reach sufficient speed to operate this magnet, the voltage across the brushes not being sufficiently high. This permits a quick action of the brake as its coil is in parallel with the high resistance *PBR* only, the *PBR'* circuit being open through contact *Q*.

A summation of the various resistances and their functions is given in the following: Increasing the resistances has the effect indicated and decreasing them gives the opposition condition.

BR—Increasing *BR* resistance decreases the total power consumption of the brake circuit.

ABR—Increasing, provides less heating and quicker application of brake shoes and eases off the blow at limit of car travel.

PBR—Increasing, provides harder application of brake at intermediate landings immediately upon centering car-switch control handle; also provides quicker application of brake when inching up or down to a landing.

PBR'—Increasing provides a harder application at intermediate floors when stopping from high speeds.

On those controllers where magnet *Q* is not used the action of the brake when inching to floors is as outlined previously, with the exception that magnet *Q* is omitted. When stopping from high speed without the use of magnet *Q* the brake application would be

harsh for that period of time only during which the direction switch releases to off position. The back contact on the direction switch upon closing cuts in *PBR′* resistance and provides for soft brake application for the remaining period of stopping.

CHAPTER VII

ALTERNATING-CURRENT BRAKES, THEIR CARE AND ADJUSTMENT[1]

Force and Time Required to Apply a Brake.—Designing an elevator brake mechanism is a problem quite different from that of designing brakes for other purposes. The time required for operation or the force of application is not usually of great importance in brakes, but each of these factors is an outstanding feature in elevator service. An elevator brake should be so designed that it can be applied in about one one-hundredth of a second.

If an elevator is operated at a speed of 180 ft. per min. (3 ft. per sec.) it will travel one inch in $\frac{1}{36}$ of a second. With an elevator at this speed a good operator will frequently make stops within an inch of the floor if the brake is responsive. This means that the total error in his judgment in determining the proper place to move the car switch to center does not exceed $\frac{1}{36}$ of a second. There are quite a number of single-speed alternating-current elevators that operate at 180 ft. per min. or faster. At least one installation is operating at 400 ft. per min., without a slow down for stopping.

A feature that is frequently lost sight of in elevator brakes is the force with which the shoes are applied to the wheel. The shoes are released and accelerated to quite a high rate of motion before they come in contact with the wheel, when they are brought to rest almost instantaneously. Stopping the brake shoes so suddenly must cause them to be applied to the wheel with a much higher force than that developed by the tension springs. This will be apparent from the following problem:

To move one pound through a distance of $\frac{1}{4}$ in. in $\frac{1}{100}$ of a second requires a force of 13 lb. If this weight of one pound is then stopped in $\frac{1}{16}$ in., it will produce a force of 42 lb. It is probable that this characteristic is the main cause of the difficulty in adjusting many elevator brakes. They are very sensitive, and if

[1] Howard B. Cook, Electrical Engineer, The Warner Elevator Mfg. Co. assisted in the writing of this chapter.

the stroke or pressure is varied but slightly, they will either grip the brake wheel or let it slide. It has been found necessary in some cases to increase the weight of the brake wheel to obtain smooth retardation.

Stopping the Car.—In alternating-current elevator work the design of a satisfactory brake is quite a different problem from that of a direct-current brake. The stopping of an elevator operated by a direct-current motor is done by the use of two brakes, the dynamic and the mechanical. Dynamic brake action is produced during the stopping period by connecting the motor's armature to a resistance, so that it becomes a generator and offers a retarding force to the elevator's motion. In this way the energy stored in the moving mass is dissipated in the form of heat in the resistance. When the speed of the motor is high, the effect of the dynamic brake is strong, but this effect decreases as the machine slows down and becomes zero when the motor stops. Under these conditions the mechanical brake has very little work to do, its chief function being to hold the car after it has come to rest; therefore the resulting action of the two brakes can be made very smooth.

An alternating-current motor cannot easily be used as a dynamic brake, particularly at low speed, consequently the mechanical brake must be of sufficient capacity to dissipate all the energy due to the motion of the parts of the machine. With single-speed alternating-current motors the mechanical brake must stop the car from full speed. If multispeed motors are used, the motor can be utilized to slow the car down to a speed corresponding to the slow speed of the motor, but below this the mechanical brake must stop the car, consequently the brake on an alternating-current elevator must be considerably larger than for a direct-current machine of a corresponding capacity and speed. An alternating-current motor of the same capacity and speed will have a considerably heavier rotating member than a direct-current machine. This, taken in conjunction with the larger brake wheel, adds to the energy that the brake on an alternating-current elevator must dissipate.

Work Done by a Brake.—Good evidence of the amount of work done by a brake is the temperature of the brake shoes and brake pulley. Brake-shoe linings that last many years in direct-current elevator service will last only a few months in alternating-current service.

In alternating-current elevator service, the heavy brake spring pressure required, produces an objectionable effect that is difficult to eliminate; that is, the abrupt stop so characteristic in this class of elevator service.

Brake Magnets.—Alternating-current brake magnets have characteristics that are quite different from those of direct-current magnets of similar design. A direct-current magnet takes the same current regardless of the position of the armature, but the pull of the magnet increases rapidly as the air gap is reduced. An alternating-current magnet takes several times as much current when the air gap is large as it does when the magnet is closed. Most alternating-current magnet coils will develop an excessive temperature and burn out if left with the current on and the armature in the open position. The pull of an alternating-current magnet is more nearly constant throughout its stroke than in the direct-current magnet. A direct-current magnet pulls more slowly and the action is smoother and softer than the alternating-current type. The action of the alternating-current magnet is more abrupt both in closing and in release. This is one of the reasons why oil dashpots are used on many alternating-current brakes.

In an alternating-current magnet, on account of the alternating magnetic field produced by the current, the magnetic circuits are made of laminated iron or steel, instead of being solid as in direct-current work. If a solid core were used for alternating-current work, the eddy current losses in it would be so high as to cause excessive heating and in other ways interfere with the satisfactory operation of the magnet. If single-phase magnets are used, a short-circuited copper loop (generally known as a shading coil) must be used in the face of the magnet core to reduce the noise when in operation. The difficulties encountered in the use of single-phase alternating-current brake magnets have caused many elevator manufacturers to use polyphase magnets. Some of these are of the plunger type, and others of the rotating type.

Brakes with Polyphase Magnets.—Figure 127 shows a cross-section through a polyphase alternating-current brake, built by the Warner Elevator Mfg. Co. In this brake a slotted laminated core supports four coils *A*, *B*, *C* and *D*. To obtain a more even distribution of the pull over the face of the magnet the coils overlap each other. On the left-hand side of the magnet, counting from the top, coil *A* is in slots 1 and 3, while coil *B* is in slots 2 and

4. Coils A and C are connected in series and to one phase, where coils B and D are connected in series and to another phase of the power supply. The armatures E are supported in loops F, which in turn are supported at the top and bottom, and act as guides for the movement of the armatures. Plungers P are also attached to loops F and act as pistons in the dashpots G. This whole structure is made up as a unit and is supported from the cover of the tank in which it is immersed in oil.

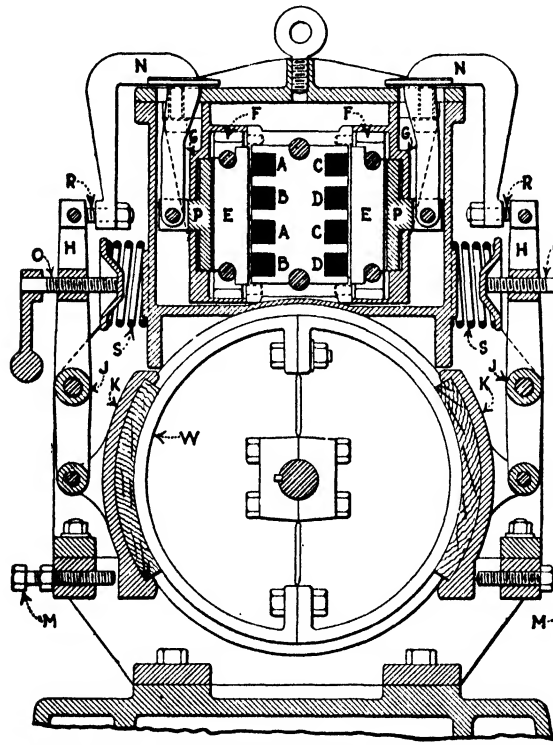


FIG. 127.—Cross-section through the brake, Fig. 128.

Connection is made between the brake levers H and dashpot pistons P by gooseneck links N. It might appear that the gooseneck links would result in a binding or twisting action. This, however, is not the case since the connection to the pistons on the inside of the oil pot is directly in line with the fulcrum-pin connection to the brake lever on the outside, and gives the same effect as a straight rod brought out through the side of the oil pot to the brake lever.

The brake-shoe levers are fulcrumed at J and the springs S, which are in compression, force the hardwood-lined brake shoes K onto wheel W. When adjusting the brake the stroke adjusting studs R are screwed into or out of the gooseneck links N until, when the magnet is closed, the shoes will just clear the brake wheel. Capscrews M are screwed in until they will just about touch the shoes. These are intended to allow the shoes free play

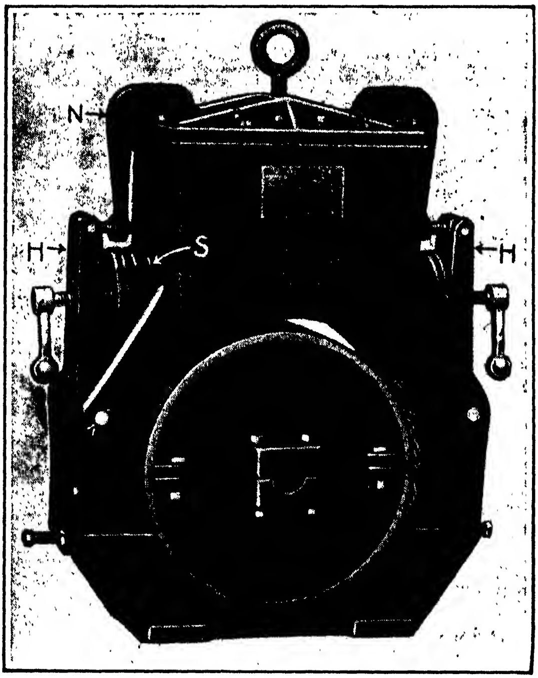


Fig. 128.—Polyphase magnet immersed in oil mounted above the brake wheel.

to adjust themselves to the wheel and at the same time prevent their top ends from falling over and riding on the wheel when the brake is released. When the brake has been adjusted to obtain the proper clearance, the force with which the shoes are applied to the wheel is adjusted by changing the tension of springs S with adjusting studs O. The same amount of tension should be given to both springs and can be determined by their length, which should be the same for each. These springs can also be seen on the complete assembly of the brake in Fig. 128.

When the coils are energized, armatures E are attracted to the core, which moves the top ends of levers H toward the magnet and the brake shoes away from the wheel and compresses springs S. De-energizing the coils releases armatures E and the springs push the top ends of levers H away from the magnet and the shoes onto the wheel. The movement of the armatures toward the magnet also moves the pistons P out of the dashpots and tends to create a vacuum, thus temporarily reducing the effective pull of the magnet. When the magnet is de-energized, the oil that has flowed

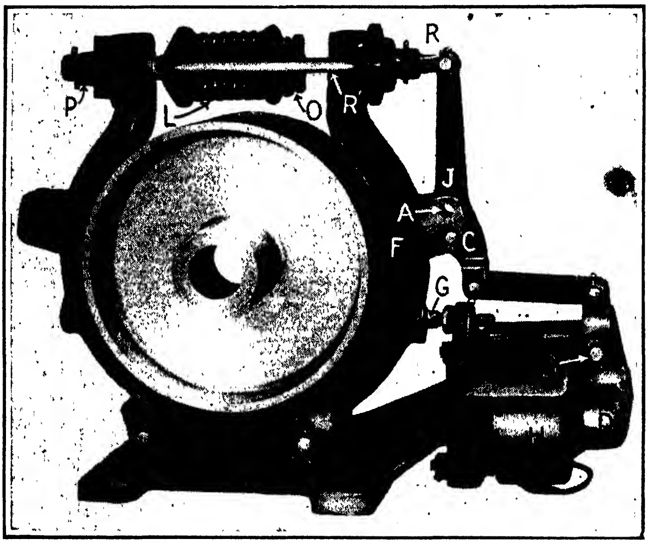


Fig. 129.—Brake for use on small direct-current and alternating-current machines.

into the dashpot is compressed and the application of the brake shoes is retarded, thus the same dashpot provides a retarding force in either direction.

Each brake is carefully tested and adjusted for rapidity of the stroke at the factory, and no attempt should be made after installation to alter the dashpot action unless abnormal conditions make this necessary. Plugs are provided in the dashpots, which can be replaced by others having suitable openings for the possible adjustment of the action in case of necessity.

It is important that the oil be maintained at the proper level in the brake magnet housing. If the dashpots are not completely

covered with oil, air will enter, causing the brake to slam, and oil will be sprayed out of the case. If oil gets on the brake shoes and wheel, the coefficient of friction will be reduced and the car will slide. The oil should be scraped off the shoes and washed off the pulley with gasoline. It should be changed about every six months, because oil sludges when subjected to heat and exposed to the atmosphere. The manufacturers use a special grade and substitutes should be avoided.

Figure 129 shows a F. S. Payne Co. brake that may be used on small direct-current or alternating-current machines and shows the general principle employed in the line of brakes built by this company. The armature *D* of magnet *H* is fulcrumed at *Q* and is connected to the lever *J* by the link *S*. This lever is fulcrumed to the brake shoe at *C* and the upper end connects to a threaded rod *R*. Rod *R* passes through clearance holes in the top of both brake shoes, but acts against the tension of spring *L* through a nut *O*. The left-hand end of spring *L* is attached to the top of the right-hand brake shoe by two rods, one on each side of the spring. One of these rods can be seen at *R′*. From the arrangement it can be seen that the spring acts on rod *R* to pull the left-hand brake shoe onto the wheel, while it acts on rods *R′* to pull the right-hand shoe against the wheel.

When magnet *H* is energized, it attracts its armature *D* and in doing so pulls the right-hand brake shoe against stop *G*. Further movement of the armature causes the top end of lever *J* to move toward the left, pushing rod *R* in the same direction against the tension of spring *L*. This releases the left-hand brake shoe and allows it to fall away from the wheel. When the magnet coil *H* is de-energized, armature *D* is released and the brake shoes are applied to the wheel by spring *L*, as previously explained.

When this brake is applied to alternating-current elevator service, a polyphase coil is used. A brake, similar to that in Fig. 129 for use on medium capacity alternating-current machines, is shown in Fig. 130. The chief difference in the two is their size; the brake Fig. 130 has its magnet immersed in oil, and the action of the brake is controlled by a dashpot. The action will be made clear by an explanation of the adjustments on Fig. 131.

To adjust the brake (Figs. 130 and 131), first remove the cover *K* from the oil container. Then adjust spring *L* so that it will exert a light pressure on the brake shoes. Following this operation adjust stop *G* so that when brake shoe *F* is released and rests

against this stop, it will clear the brake wheel by the smallest amount possible and yet give a running clearance. Next adjust nut *P* to a position that will allow shoe *E* to clear the pulley by the smallest running clearance when the brake is released and shoe *F* is against stop *G* by pressing armature *D* against the magnet core *H*. When trying the movement of the brake, it is necessary to apply the effort directly to armature *D*, otherwise lost motion in the mechanism may lead to wrong conclusions regarding the adjustment. Armature *D* may be moved by a small lever prying against it and over the top edge of the oil pot as a fulcrum. The

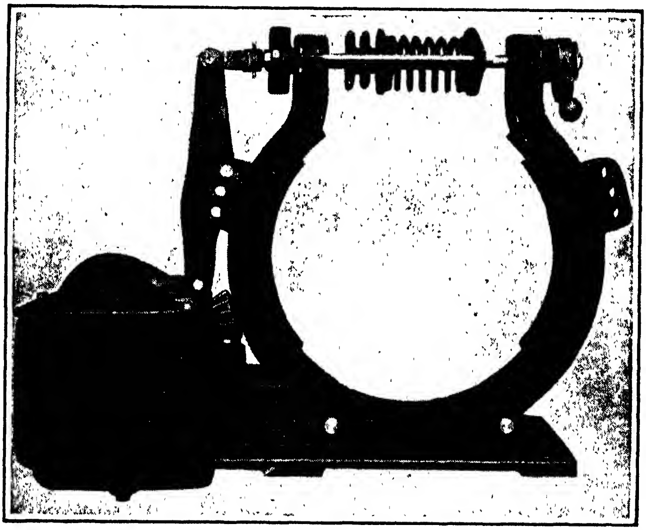


FIG. 130.—Brake for use on medium-capacity alternating-current machines.

most satisfactory operation of the brake will be obtained when adjusted for the smallest possible movement of the brake shoes, which will be when armature *D* has a movement of ¼ inch.

For direct-current, lever *J* is connected to brake shoe *F* with a pin in the bottom hole, as this permits operating the magnet with a shorter air gap. For alternating current, the top hole is used. Although the air gap in this case is somewhat increased, there still obtains practically the same pull, but with a better leverage on the shoes. This gives a somewhat stronger brake for alternating-current work, which is desirable, as the brake has to be relied on entirely for making stops, since dynamic braking cannot be used as is possible on direct-current applications.

For alternating-current brakes put transformer oil in the oil container until the brake magnet coil is just covered. No oil is necessary in direct-current brakes. After the oil has been put into the container, adjust the dashpot vent screw *M* to a position that will give a decided retarding effect when armature *D* is moved by hand to the position where the brake is released. Vent screw *M* is adjusted by one-half turn and is locked by means of a yoke *N*. The brake coil can now be energized and then de-energized and the action of the brake observed. A readjustment of vent screw *M* will probably be necessary. Adjust this vent screw

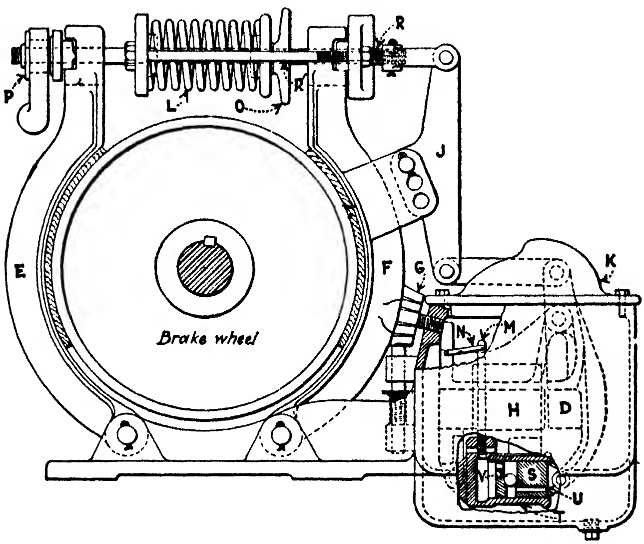


FIG. 131.—Cross-section of the brake, Fig. 130.

so as to get the proper retarding effect on armature *D*. This will be when the blow observed in closing the magnet is at a minimum, but care must be taken not to close vent *M* to where it will cause the brake to be late in releasing.

The brake having been adjusted for proper movement, turn up on nut *O* until the desired brake-shoe pressure is obtained. This can be checked by the way that the brake stops the car. The brake shoes are lined with an asbestos fabric interwoven with brass wire and, until they get thoroughly fitted to the wheel, may require frequent adjustment.

The dashpot consists of a cylinder *T* and a piston *S* attached to armature *D*. When the brake is applied to the wheel, piston *S*

is in the position shown in the figure and oil flows through the passageway *U* in the piston, by the ball check valve *V* and into the bottom of the cylinder. When the magnet coil is energized and attracts armature *D*, it pushes piston *S* into the cylinder and forces the oil out by the check valve *M*, since the ball valve *V* prevents it from flowing back through the passage by which it entered the cylinder.

Where a brake of larger capacity is required than that shown in Figs. 130 and 131, the type illustrated in Fig. 132 is used, which is designed particularly for heavy duty freight elevators or high-speed passenger elevators. This brake operates on the same

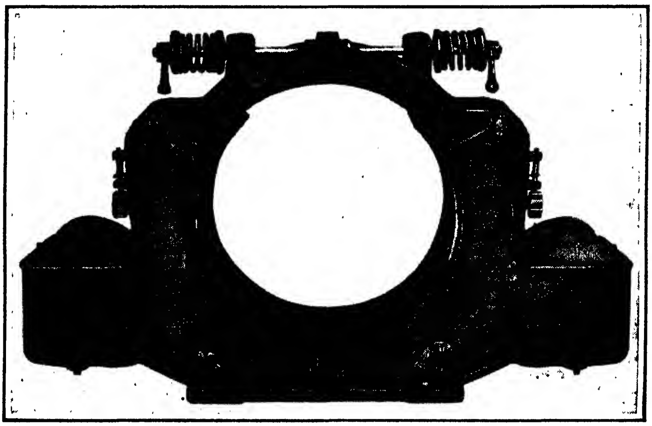


Fig. 132.—Brake with two magnets for use on large-capacity machines.

principle as the one in Figs. 130 and 131, the only difference being that each shoe is provided with an independent releasing magnet and is virtually two brakes in one. In this type, each shoe is adjusted independently and in the way previously explained for the brake with a single coil. In adjusting the dashpots care must be exercised to have them functioning so that both shoes will release at the same time.

Brakes Operated by a Torque Motor.—A rotating magnet as applied to alternating-current brakes is simply a small high-torque squirrel-cage polyphase induction motor, so designed that it can remain stalled on the line indefinitely. Figures 133 and 134 show a Cutler-Hammer brake of this type. It is operated by lever *K*, which is fulcrumed in the right-hand brake-shoe support at *O*, and has its upper end attached to the left-hand brake-shoe

support by the push rod H. The magnet's shaft is geared to quadrant Q, which is supported on the shaft M. An extension from the bottom of this quadrant is connected to the lower end of

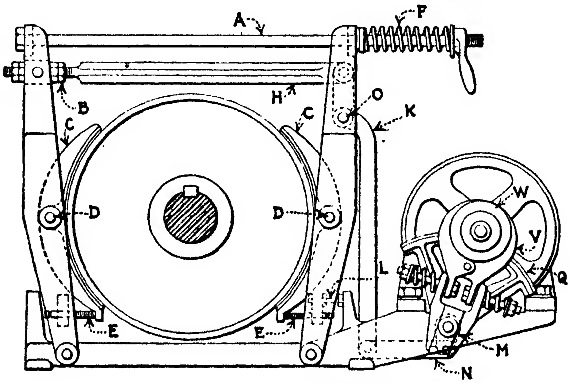


FIG. 133.—Drawing of brake, Fig. 134.

lever K by the link N. When the magnet is energized, it rotates in a clockwise direction, which turns the quadrant in a counter-clockwise direction. This motion causes link N to be pulled to

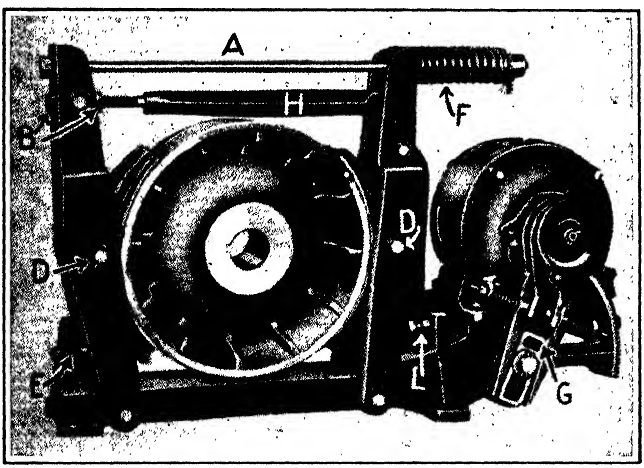


FIG. 134.—Alternating-current brake released by a torque motor.

the right and with it the lower end of lever K and, as previously explained, this motion of lever K releases the brake. At the end of its travel the magnet is stopped by an auxiliary brake V closing on a stop wheel W.

A more detailed picture of the mechanism for connecting the magnet to the brake is shown in Fig. 135. The pinion and dog *D* are rigidly fastened together and keyed to the rotating magnet. A stop wheel *W* is bushed on the shaft and is driven by dog *D*, which engages a projection cast on the inside of the stop wheel. There is a one-half revolution of lost motion between the stop wheel *W* and dog *D*. When the quadrant *Q* has reached near its limit of travel in either direction, a rib on the quadrant arm

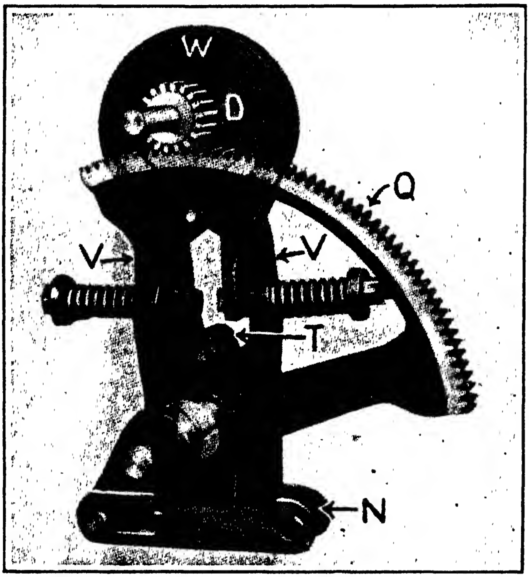


Fig. 135.—Operating mechanism that connects torque motor to brake, Fig. 134.

engages a projection *T* Fig. 135, on the cam block shown at *G* in Fig. 134, and turns it. Turning of cam block *G* spreads the arms *V*, which applies the brake to the stop wheel *W*. The lost motion between dog wheel *D* and stop wheel *W* allows the magnet to revolve freely in the opposite direction while the auxiliary stop brake is releasing. A lost motion slot is provided in link *N* so that the main brake shoes can apply before the auxiliary brake applies. The brake should be so adjusted that when the shoes are applied to the wheel the pin will be about in the center of the slot in link *N*.

The magnet coils are wound for either two-phase or three-phase and are connected to the line in the same way as a two-phase or a

three-phase motor. After the magnet has been connected, if it rotates in the wrong direction it can be reversed in the same way as an induction motor wound for the same number of phases and connected in the same way.

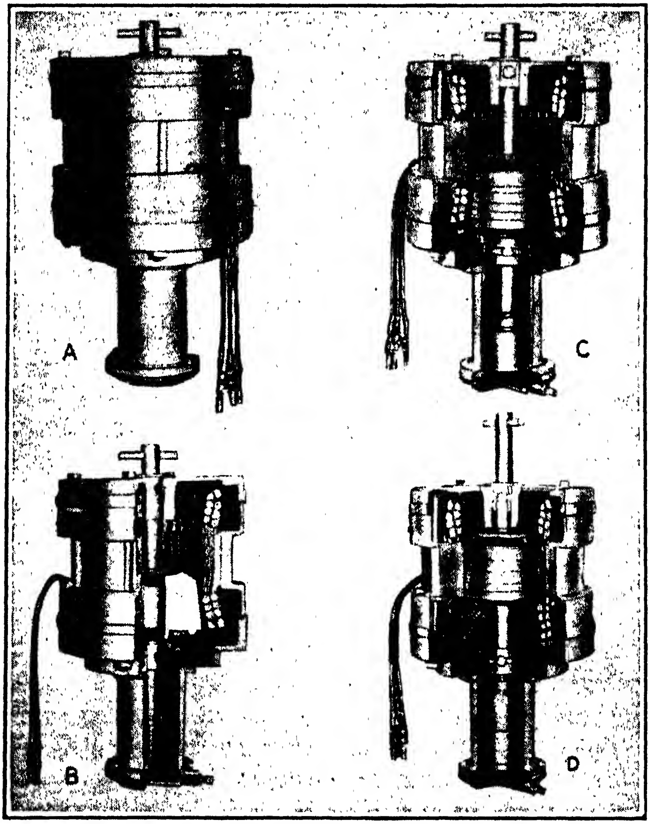


FIG. 136.—Complete assembly and sections of non-sealing type brake magnet. *A*—Complete assembly of brake magnet. *B*—Section through stator and movable core. *C*, Section through stator, showing movable core in released position. *D*—Section through stator, showing the movable core in the full-stroke position.

When the brake is being adjusted, compress spring *F* until the brake shoes apply quite tightly to the wheel, then adjust nuts *B* until the crankpin is at the center of the slot in link *N*. After these adjustments have been made, release the brake by energizing the magnet and equalize the clearance between the center of the shoes and brake pulley by screw *L*. This clearance should be

about $\frac{1}{32}$ in. The clearance at the top and bottom of the shoes can be equalized by the screws E.

When the clearances have been properly adjusted, check the operation of the brake by starting and stopping the elevator. Spring F should be adjusted to give a smooth quick stop, but the spring should not be given a tension that will cause the brake to act sluggish when released.

Non-sealing, Reciprocating-type Brake Magnet.—The brake magnet, Fig. 136, used by the Haughton Elevator Co., is non-sealing and is of the polyphase rotating-magnetic-field type, but reciprocating in operation instead of rotating. As seen in the figure, the stationary part is similar to a polyphase induction motor's stator with a laminated core and a distributed winding. The rotor has a laminated core without a winding displaced out of line with the stator when the magnet is in the open position, as shown in C. There is no rotative effort but a tendency for the core to align itself with the stator when the latter winding is energized. It will be seen that since the rotor core tends to align itself with the stator core, it does not require a mechanical stop and therefore cannot cause a slapping noise. Because a polyphase distributed winding on a magnet produces a pull that is always considerably above zero, it will not cause a magnetic hum or vibration. By shaping the core face it is possible to produce practically any characteristic stroke-pull curve desired, and as the constant pull is most desirable for brake service, this is used so as to eliminate any violent action of the magnet.

There are many other makes and designs of alternating-current elevator brakes, but the ones herein described are representative of the general principles involved. The brake mechanisms in general are not radically different from the direct-current type, the chief difference in most cases being in the magnet's construction, the use of dashpots and the immersing of the magnets in oil.

CHAPTER VIII

DIRECT-CURRENT SEMI-MAGNET CONTROLLERS

Types of Controllers.—Elevator controllers may be divided into two general classes, semi-magnet and full-magnet. The semi-magnet types are those used on elevators that are operated by a hand rope in the car. The operator may control the elevator either by pulling on the rope directly or through the medium of a lever or wheel. On the semi-magnet control, the reverse switch is generally operated directly by the operator in the car, through the operating cable, after which the starting resistance is cut out of circuit automatically by a magnet.

Sometimes the semi-magnet control is referred to as a mechanical type. This, however, is not correct, since it would indicate that all the functions of the controller were performed mechanically. In most cases where elevators are controlled with a hand rope, part of the control functions are performed by a magnet or magnets, hence the name semi-magnet control.

Some of the earlier type of elevator controllers were constructed so that all their functions were performed mechanically, no magnets being used in their operation. Such control systems may be classed as a mechanical type, but today they are seldom found in use.

Broadly, full-magnet controllers are those in which all the functions of the control are performed by magnets. The initial impulse for starting and stopping the car may be from a car switch or push button, after which the controller completes the operation automatically. These types of controllers may be divided into car-switch control, automatic leveling, automatic landing, push button, signal control, dual control, etc., depending upon what the control equipment accomplishes.

Compound Motors.—Semi-magnet controllers are generally designed for but one speed, that is, the car can be run at full speed only, no slow down being provided, consequently the equipment is only applicable to slow-speed machines. Compound motors are usually used, with the armature, shunt-field coil and

series-field coil leads brought out to separate terminals. When the motor is running full speed, it is a shunt machine, the series-field coils being cut out, through the accelerating magnet, as this will allow better speed regulation under various loads.

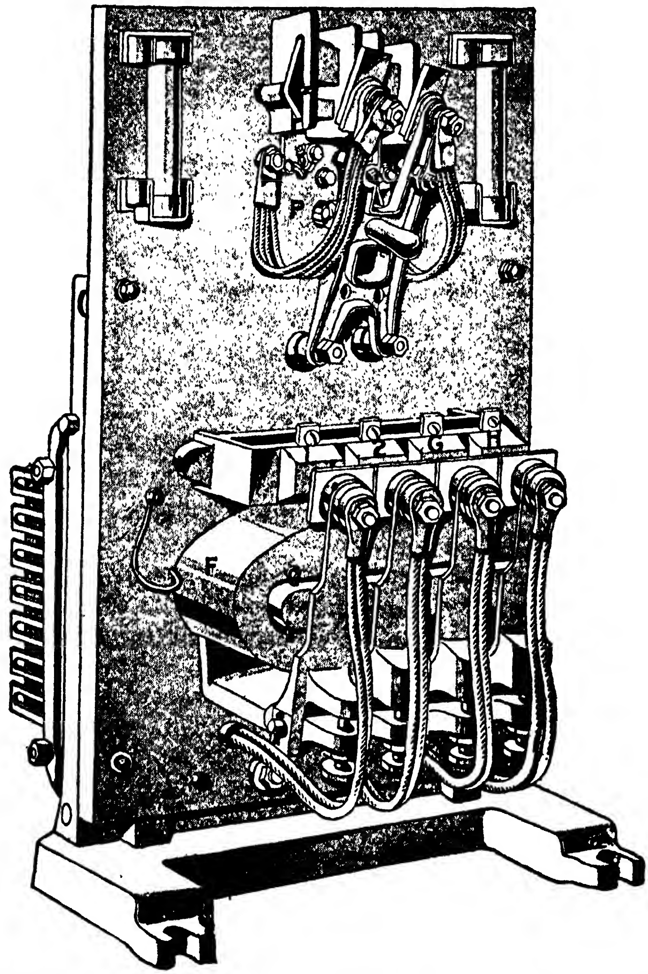


Fig. 137.—Elevator-controller accelerating magnet and potential switch.

Counter-electromotive-force Type Controllers.—The controller, Fig. 137, which is one type used by the Otis Elevator Co., consists of a main line or potential switch *P*, that is open when the machine is at rest and is closed by a magnet coil through contac-

tors operated by a cam, located at *A*, Fig. 138. The potential switch is provided with a magnetic blowout coil to prevent the arc being carried between the contacts when the switch is opened. The accelerating magnet *F* is a coil of fine wire fitted over an oval-shaped core on which are arranged four contact arms, two of which (1 and 2) cut out sections of the starting resistance and the other two (*G* and *H*), cut out the series-field coils. These arms are adjusted so that No. 1 is set nearest the core and *H* is the

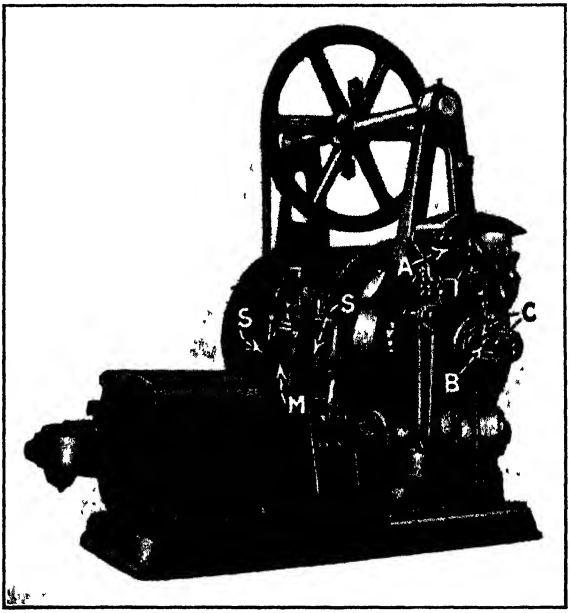


Fig. 138.—Single-geared drum-type electric-elevator machine.

farthest away. The coil is connected across the armature, therefore the voltage will be increased across its terminal as the pressure increases across the armature terminal, consequently producing a stronger magnetic effect, which will draw in the contact arms one by one, depending upon the distance they are located away from the coil. This type of controller operates on the counter-electromotive force principle as explained later in this chapter.

Cams operate contact arms placed at the end of the drum shaft, as shown at *A*, in Fig. 138. The contacts on cams III and IV, shown on the controller wiring diagram Fig. 139, close first and

control the direction of the motor. These contactors operate diagonally; that is, contact 6 on cam III and contact 8 on cam IV close at the same time. Assume that these two contactors control the up-motion of the car, then contacts 5 and 7 will control the down-motion. Both the contactors on cam I close second; contactor 1 completes the brake-coil circuit and 2 the accelerating-magnet-coil circuit. Both contactors on cam II close after those on I; these contactors close the main-line or potential-switch coil circuit by completing the circuit through the magnet coil and safety-device circuit, which includes the safety switch in the car, the slack-cable switch, the governor switch, the upper- and lower-limit switches and the door contactors. If any of these devices

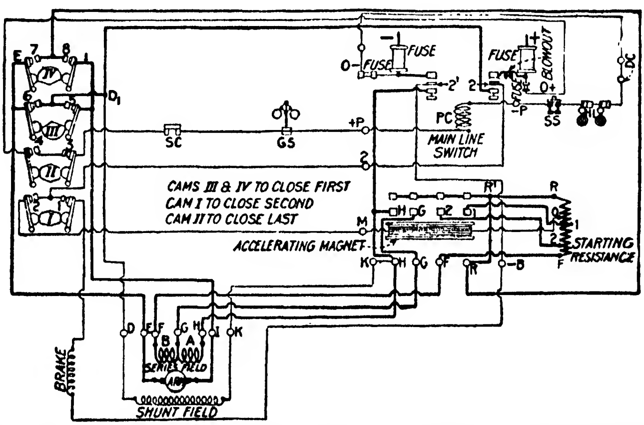


FIG. 139.—Diagram of controller Fig. 137, all switches in the off position.

are open, the potential switch cannot close, therefore the motor will not start. When stopping the machine, the contacts on cam II open first, causing the main-line or potential switch to open, and the brake is then applied, which will bring the machine to a full stop. The brake shoes are raised by an electromagnet M, Fig. 138, and are applied by the heavy spiral spring S.

Stopping at Terminal Landings.—When the car reaches the upper or lower end of the hoistway, there are three limit appliances which will stop it, if anything should happen to the operator or go wrong with any part of the machinery or car while it is running.

The first stopping device is the stop balls, which are clamped to the hand-rope at the top and bottom landings. These balls

strike a fitting, fastened to the top of the car, through which the hand-rope passes and performs the function of the operator by pulling the operating cable up or down, depending upon the motion of the car. Should this safety device fail, the traveling nut *B*, Fig. 138, on the end of the drum shaft will be caught by one of the fixed nuts *C* and act to bring the machine to rest. The third safety device is the upper- and lower-limit switches in the shaft, which are in series with the magnet coil on the potential switch. By opening the circuit of this magnet coil, the switch will drop out and open the line. These safety stops are located at the upper and lower end of the hoistway, to prevent the car from being jammed into the overhead work or striking the bottom of the pit.

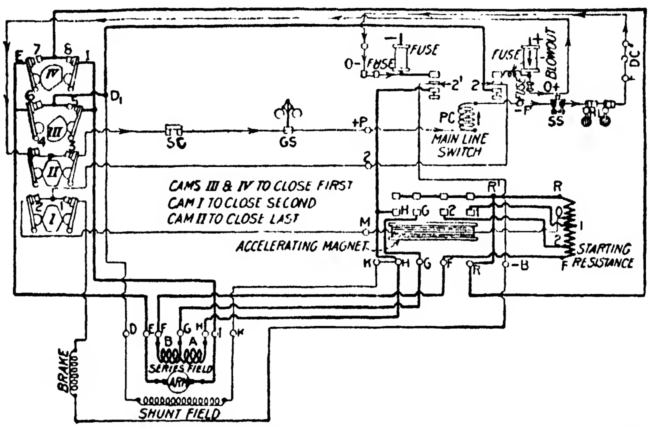


FIG. 140.—Same as Fig. 139, with potential-switch-coil circuit closed.

Operation of a Counter-electromotive-force Type Controller. When the operator in the car pulls the hand-rope down to start in the up-motion, the cams will close the contactors, as shown in Fig. 140; that is, cam IV will close contact 8, cam III contact 6, cam II will close contacts 3 and 4, and cam I contacts 1 and 2. As previously explained, contacts 3 and 4 close last and complete the circuit from the positive side of the line, through the slack-cable switch *SC*, the governor switch *GS*, the potential-switch coil *PC*, the safety switch *SS* in the car, the upper- and lower-limit switches *HL* in the hoistway, the door contacts *DC*, and back to the negative side of the line, as indicated by the arrowheads.

With this circuit energized the potential switch closes, as shown in Fig. 141, which completes the motor, brake-coil and accelerating-magnet-coil circuits. The armature circuit is from the positive side of the line, through the blow-out coil of the potential switch, through the heavy conductor to contact 6 on cam III, from here to terminal *E* on the armature, through the armature to terminal *I* and back to contactor 8, which is closed, from here to terminal *R* on the control board, and through the starting resistance to terminal *F* on the series-field coils at the motor, through the series-field winding to terminal *H* and back to the negative side of the line, as shown. The shunt field is energized from a tap taken from the wire at cam III, at point D_1, from here to

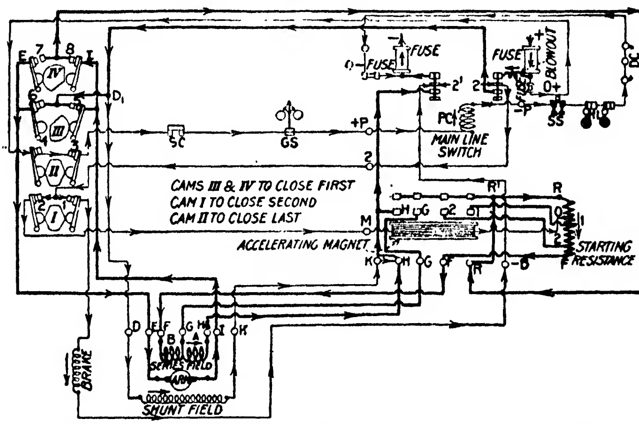


FIG. 141.—Same as Fig. 139 with controller in one on position.

terminal *D* on the motor, through the shunt field to terminal *K* on the control board, which connects with terminal *H*, and back to the negative side of the line, as indicated.

The brake-coil circuit is from contact 2 on the positive side of the potential switch to contact 1 on cam I, through the brake-magnet coil to terminal $-B$ on the control board, and to contact $2'$ on the negative side of the potential switch.

The accelerating-magnet-coil circuit is completed through contact 2 on cam I, and the flow in the circuit is from contact 2 on the potential switch to contact 2 on cam I, to terminal *M* on the controller board, then through the accelerating-magnet coil to *O* on the starting resistance, through the starting resistance to terminal *F* on the controller, the series-field coils to *H*, and back

to the negative side of the potential switch as indicated by the arrowheads.

With the circuits closed, as explained in the foregoing, the motors should start and increase in speed; then, as the voltage across the armature terminals is increased, the magnetic pull of the accelerating-magnet coil will be increased and resistance contact 1 will close. This will short-circuit part of the starting resistance out of the armature circuit and cause the motor to increase its speed, and then contact 2 will close and short-circuit another section of the starting resistance. The path of the current through the controller with resistance-contact arm 1 and 2 closed, will be as shown in Fig. 162. In this case the circuits are

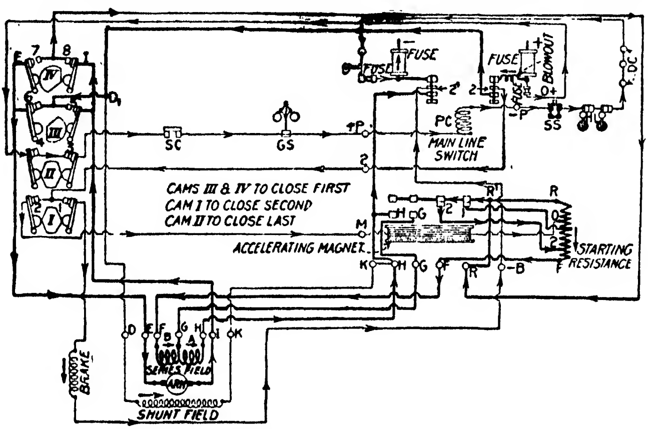


FIG. 142.—Same as Fig. 139, with controller in one on position and contactors 1 and 2 on the accelerating magnet closed.

practically the same as in Fig. 141, except instead of the armature current flowing through all the starting resistance, it only passes through the section between 2 and *F*, the circuit being from *R* to *R'* to contact arm 2 on the accelerating magnet and to point 2 on the starting resistance to terminal *F* of the series field, through the series field to terminal *H* and back to the negative side of the line. The motor is now running at very nearly full speed, as a compound machine with a small section of a starting resistance still in the circuit.

The next contact arm to be drawn in is *G*; this will cut out one of the series-field coils *B* and the remaining portion of the starting resistance, which will further increase the speed of the motor; then contact arm *H* will be drawn in. This cuts out the other

series-field coil A, and the motor is now running as a shunt machine at full speed.

The direction of the flow of the current is shown in Fig. 143 and is from the positive side of the line to contact 6 on cam III,

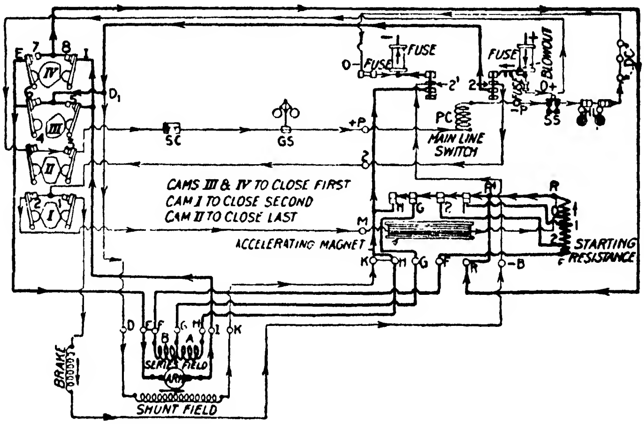


FIG. 143.—Same as Fig. 139, with controller in one on position to give full motor speed.

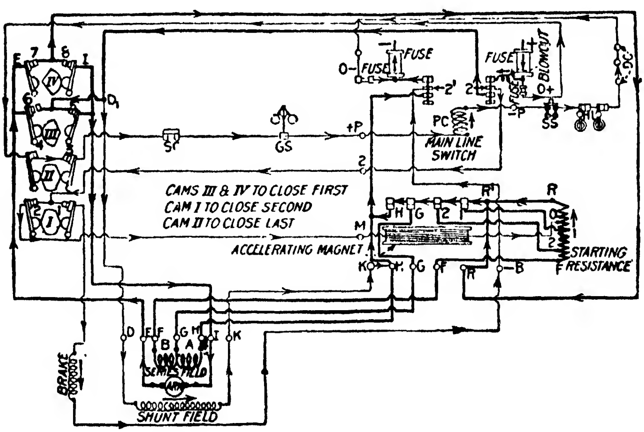


FIG. 144.—Same as Fig. 143, except connections are made for reverse rotation of the motor.

to terminal E of the armature, through the armature to terminal I, to contactor 8 on cam IV, from here to terminal R on controller board to R', then through contacts 1, 2, G and H, to the negative side of the line.

To reverse the direction of the motor the cams are thrown to the opposite position, as shown in Fig. 144. It will be seen that contacts 5 and 7 on cams III and IV are closed instead of contacts 6 and 8. By tracing out the circuit, it will be found to be the same as in Fig. 143 except the direction of the current through the armature, which is reversed as indicated by the arrowheads. At the top and bottom landings the car will be stopped automatically as previously explained.

Operation of Time-limit Type Controllers.—Figure 145 shows the diagram for one type of Cutler-Hammer semi-magnet controller. This has a cylindrical reversing switch, such as shown in Fig. 146. The starting resistance is cut out of circuit by a solenoid S, Fig. 147, which moves the arm F over the contacts R, in much the same manner as it is done by hand on the simple manual-type starter. The oil dashpot P regulates the time required for the solenoid to cut out the starting resistance. As the dashpot is adjusted for a definite time, the controller is known as the time-limit type. A magnet switch M opens and closes the circuit in response to the motion of the reversing switch.

Figure 145 shows a diagram of the connections with the main-line switch closed and the reversing switch in the neutral position. The parts 1, 2, 3, 4 and 5 are segments attached to the movable element of the reversing switch. If the switch segments are moved to the left, 1 will make contact with L and C, 2 with N, 3 with A', 4 with S_2 and 5 with A_1. When segment 1 makes contact with L and C, it completes the circuit for coil M on the main-line contactor. This circuit is from the + side of the line to L on the controller, through the slack-cable switch and the overtravel limit switches and to L on the reversing switch. From L the circuit is through segment 1 to C, through coil M, resistance H, F arm on the controller to the − side of the line. Completing this circuit energizes coil M and causes it to close its contactor and establish the motor circuits.

The motor's armature circuit is from the + side of the line through contactor M to N on the reversing switch, through segments 2 and 3 to A', and to A_2 terminal of the motor's armature. From here the circuit continues through the armature and returns to A_1 on the reversing switch, through segments 5 and 4 to S_2 on the controller and through the series-field winding back to the S_1 terminal on the controller, through all the starting resistance R and to the − side of the line. Closing contactor M also com-

pletes the circuit for solenoid S, from E through coil S to A and through jumper T around resistance R', between contacts A and B, to the $-$ side of the line.

Energizing S causes it to start raising arm F to cut out the starting resistance. When the arm moves off the first contact, it cuts resistance D in series with coil M and reduces the current in this coil. The reason for doing this is, that it requires much less current in the coil to hold the contactor closed than it does to close it. It also keeps down the temperature of the coil and

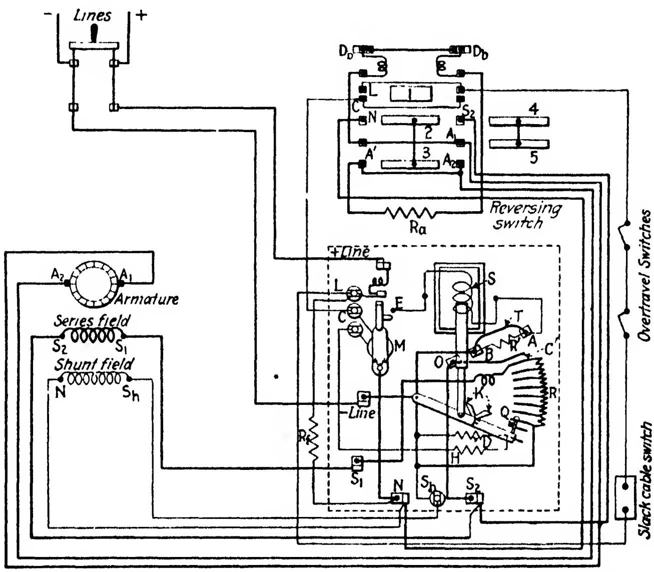


Fig. 145.—Wiring diagram for controller, Figs. 146 and 147.

saves power. When arm F rests on next the top contact, C', the starting resistance R is cut out of circuit and the motor is operating at full speed as a compound machine which is considerably slower than the speed obtained with the shunt winding only.

In its top position arm F rests on contact C', and in this position the series-field winding is cut out of circuit. Arm F is also short-circuited by contacts K striking terminal blocks B and O. The armature circuit is now from S_2 at the bottom of the controller to the series winding, and converts the motor into a shunt machine. It is necessary to cut the series winding out on a compound elevator motor after it has come up to speed to prevent the elevator

from operating above normal speed in the down motion with a heavy load. When lowering a heavy load, the motor is converted into a generator and pumps back into the line, this causing the motor to act as a brake to keep the car under control.

When a compound motor is converted into a generator, the direction of the current in the series winding is reversed and opposes the shunt-field winding. If the series winding were not cut out, the machine would be operating with a decreased field and consequently the braking action would be reduced. To overcome the difficulty, the series winding is cut out of circuit after the motor has come up to speed. Cutting out the series

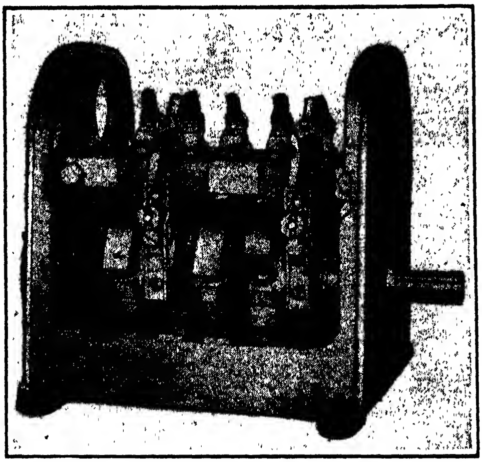


Fig. 146.—Cylindrical-type reversing switch.

winding after the motor comes up to speed also improves the speed regulation, as a shunt motor has a more constant speed under varying loads than the compound type.

Contact *Q* on the arm *F* strikes jumper *T*, which breaks contact with *A* when the arm is in the uppermost position. When *T* breaks contact with *A*, resistance *R'* is put in circuit with coil *S* and reduces the current in this coil, for the same reason as explained for coil *M*.

In this controller the dynamic-braking action of the motor is used to help the mechanical brake stop the elevator. For this reason the shunt-field winding is connected permanently across the line. With the reversing switch in the neutral position, the shunt-field circuit is from the + side of the line through resistance

R_f to N at the bottom of the controller, through the shunt-field winding, back to the S_h terminal on the controller and to the − side of the line. When contactor M closes, the shunt-field circuit is directly through contactor M to terminal N, cutting out resistance R_f. Putting resistance R_f in the field circuit when contactor M opens, reduces the field current, but at the same time maintains a field to cause the motor to develop a dynamic braking action to help stop the elevator.

To stop the car, the reverse switch is brought to the neutral position by the operator, which cuts the power out of the motor

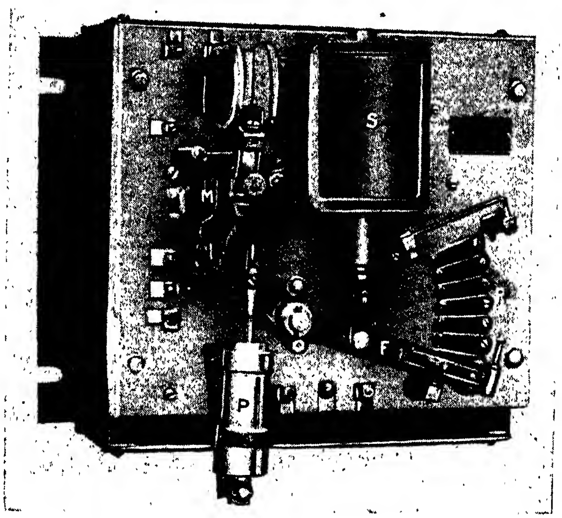


FIG. 147.—Semi-magnet type controller for medium-sized motors.

and connects the armatures through resistance R_a. The dynamic braking circuit is from the A_2 armature terminal to A_2 on the reversing switch, through resistance R_a, contacts D_b on the reversing switch and to the A_1 terminal of the armature. This completes the armature circuit for it to act as a generator during the stopping period. When the reverse switch is in either on position, contacts D_b open and prevent connecting the dynamic-braking resistance across the armature.

In the reverse direction, the circuits are the same as already explained except that the reverse switch is closed to the opposite position and the direction of the current is reversed through the armature.

The control diagram, Fig. 145, is for an equipment that employs a brake that is released mechanically, such as shown in Fig. 115, Chapter VI. Figure 148 is the connection diagram of a semi-magnet controller with a compound magnet for releasing the brake. This controller is also equipped with a no-voltage relay to prevent the car starting with the return of voltage, should the controller be left in the on position when power is off the line.

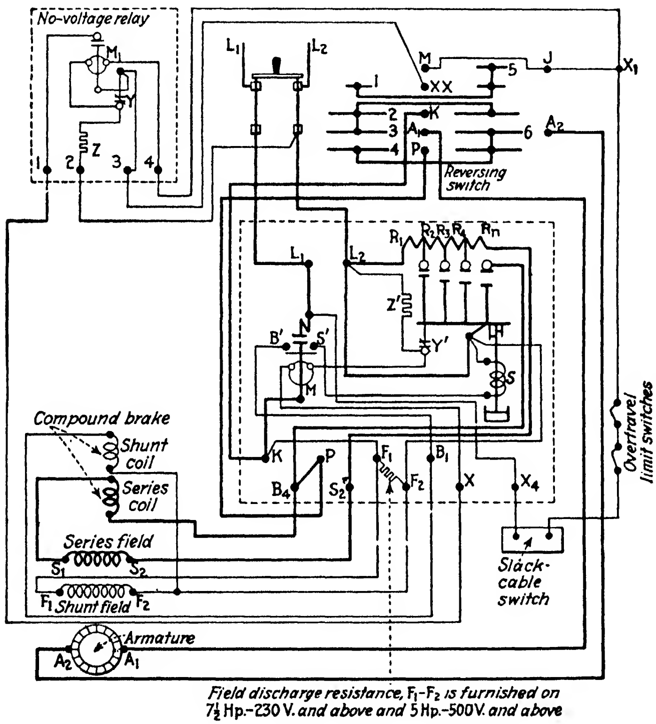


FIG. 148.—Wiring diagram for the controller shown in Fig. 149.

The complete control equipment is shown in Fig. 149. In this arrangement the reversing switch *S* is mounted on top of the controller and can be connected to the shipper wheel on the elevator through a sprocket chain or other form of gearing. On the left-hand side of the controller is the line contactor *M* and on the right is the accelerating switch for cutting out the starting resistance. In the center of the panel board is mounted the no-voltage relay *N*. Instead of the resistance being cut out by a solenoid moving an arm over a series of contacts as in Fig. 145, on the

controller Fig. 149, the solenoid closes a number of contact fingers C.

In Fig. 148 the no-voltage relay is closed all the time that power is on the line. The closing circuit for this relay is from the L_2 side of the line switch, through resistance Z, coil M_1, the overtravel limit switches, the slack-cable switch to the X_4 terminal on the controller and the L_1 side of the line. As long as this circuit is energized, the no-voltage relay remains closed. If the power is off and the reversing switch is closed, the relay cannot close when power returns to the line, until the reversing switch is placed in the neutral position.

Assume that the reversing switch is closed to the right, then the cylindrical segment 1 will make contact with XX, 2 with K, 3 with A_1, 4 with P, 5 with J and 6 with A_2. Assuming that the no-voltage relay is open and the reversing switch closed, a circuit is provided from the L_2 side of the line through resistance Z and contact Y on the no-voltage relay to contacts XX and J on the reversing switch, around through the overtravel limit switches to the L_1 side of the line. This cuts the closing coil out of the circuit on the no-voltage relay. Therefore with the return of power on the circuit this relay cannot close until the reversing switch is pulled to the off position. When the no-voltage relay closes, it opens contact Y and interrupts the circuit through the reversing switch and prevents the relay coil from being short-circuited.

With the no-voltage relay closed and the reversing switch closed to the right, a circuit is provided for line contactor M, from the L_2 side of the line through the bottom of the accelerating switch, contact Y', coil M to X at the bottom of the controller, through the top contact on the no-voltage relay, to contact XX on the reverse switch and through the limit switches to the L_1 side of the line. Energizing coil M causes it to close its contactor. In doing so, it closes three circuits—one for the shunt coil on the brake, one for the solenoid on the accelerating switch and one for the motor.

The shunt brake-coil circuit is from the L_2 side of the line to the F_2 terminal on the controller, through the shunt brake coil back to the control panel, to the B' contact on line contactor M and to to the L_1 side of the line. The circuit for solenoid coil S is from the L_2 side of the line through this coil, to contact S' on the contactor M and to the L_1 side of the line. For the motor, the circuit

is from the L_2 side of the line, through the starting resistance between R_1 and R_n, through the series windings on the motor and the brake to B_4 terminal on the controller and P on the reversing switch, then to A_2 and through the armature back to A_1 on the reversing switch. From A_1 on the reversing switch, the circuit is to K on the controller, through contactor M and to the L_1 side

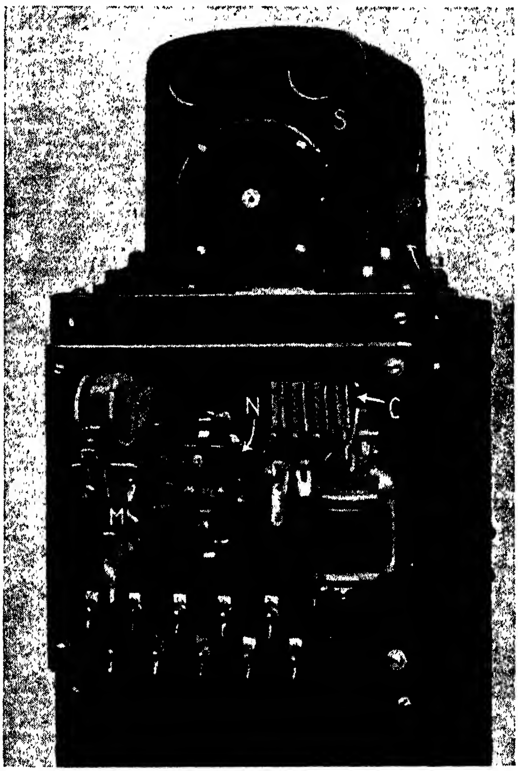


FIG. 149.—Semi-magnet type controller combined with reversing switch for medium-sized motors.

of the line. The combined effort of the two coils releases the brake and the motor starts.

The shunt field of the motor is connected directly across the line to terminals F_1 and F_2 on the controller. As the motor comes up to speed, coil S pulls up its core and closes contactors R_2, R_3, R_4 and R_n, thus cutting the starting resistance out of circuit. Closing of R_n contact, cuts the series windings out of circuit on

the motor and the brake. With the R_n contact on the accelerating switch closed, the armature circuit is directly from the L_2 side of the line, through contact R_n to B_4 terminal on the controller and to P on the reversing switch, thus connecting the armature directly to the line and bringing it up to full speed.

When solenoid S closes the accelerating switch, it opens contact Y' and connects resistance Z' in series with coil M. This resistance performs the same function as explained for coil M in Fig. 145.

With the controller, Fig. 148, no provisions are made for dynamic braking and the shunt-field winding circuit is opened each time the motor is stopped. To prevent an excessive voltage being induced in the field winding when it is opened, a discharge resistance is connected to terminals F_1 and F_2. For a short period after the motor is disconnected from the line, the induced voltage in the field coils will cause a current to flow through the resistance and prevent the voltage in the field winding from rising excessively above normal.

At the top and bottom landings with drum-type machines, the mechanical limits on the drum shaft or the stop balls on the operating cable bringing the reverse switch to the neutral position. On traction-type machines the stop balls on the operating cable are the only mechanical limits. In this way the elevator is automatically stopped. If for any reason the limits failed to function properly, the car would, on passing the floor a short distance, strike one of the overtravel limit switches in the hatchway and open it. Opening of the overtravel limit switch interrupts the circuit to the no-voltage relay coil and causes the relay to open, and opens the circuit to the coil on contactor M. This contactor would then open and cut the power out of the motor and apply the brake.

After the elevator car has run onto one of the overtravel limit switches, the motor cannot again be started until the car is raised by hand or by holding the no-voltage relay closed by hand so that contactor M will close when the controller is pulled to the reverse position.

Segments 1 and 5 on the reverse switch are made shorter than 2, 3, 4 and 6. This is done so that the armature circuit will be closed before the coil circuit of contactor M, and will open after the coil circuit to contactor M opens. Thus, all the making and

breaking of circuits having heavy currents is done on contactor *M*, which is designed for this service.

On controllers for motor sizes from 25 to 50 hp., the type shown in Fig. 150 is used. On this type, switch *A* is not used to cut out the starting resistance directly, but acts as a pilot switch that closes the circuits to the contactors *B*, *C*, *D* and *E*, which function and cut out the starting resistance. Contactor *E* opens first and

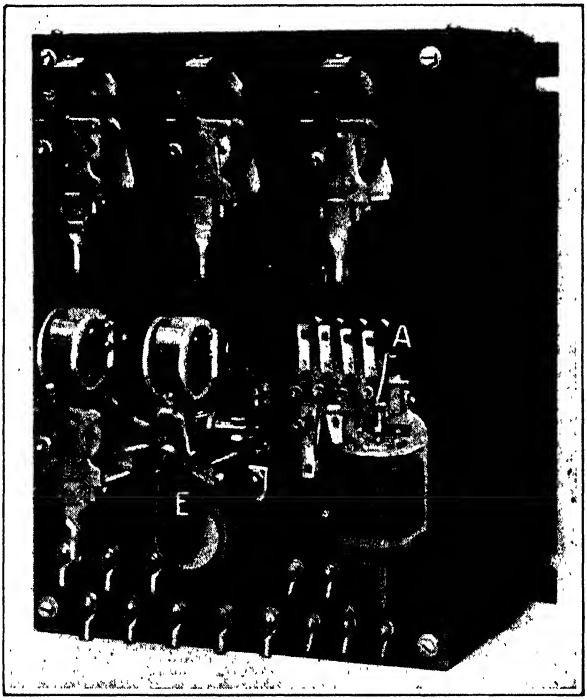


FIG. 150.—Semi-magnet type controller for large-sized motors.

disconnects the dynamic-braking resistance from the armature, after which contactors *B*, *C* and *D* close and cut out the armature series resistance. When stopping, contactor *E* is closed by a spring and connects the armature through the dynamic-braking resistance, which causes the motor to develop a retarding force to assist the mechanical brake to stop the car. Contactor *M* opens and closes the main-line circuit as on the other types of controllers, Figs. 147 and 149.

CHAPTER IX

TWO-SPEED DIRECT-CURRENT MOTOR CONTROLLERS

Number of Speed-control Points.—Elevators operating at a car speed of 100 ft. per min. or less can be controlled with a single-speed controller without any slow-down. At higher speeds slow-downs must be provided in the control equipment so that the operator can reduce the speed of the car so that an accurate landing can be made.

For example, if a car operates at 150 ft. per min., the control equipment can be arranged to give two speeds, say 75 and 150 ft. per min. The motor on such an equipment would operate at a speed with all the starting resistance and the series field winding cut out, to give a car speed of 75 ft. per min. To obtain the 150 ft. per min. car speed, the field current is reduced to double the motor's speed. Another method of obtaining two speeds is to use two shunt-field windings, one of which is cut of circuit to obtain the high car speed. The higher the car speed the greater the number of speed-control points that must be provided. Some controllers have seven or more speed points on the car switch.

Circuits in the Controller.—The Gurney Elevator Co.'s controller, Fig. 151, is one type designed to give two car speeds from the car switch and is known as the type 42-*B*. What the different contactors are for is given under the figure, and how the controller functions will be made clear by the following description of the circuits shown in Fig. 152, which are for a traction elevator machine.

On this type of controller the up or down direction switches *U* and *D* also act as a line switch to make and break the line circuit, and they are equipped with blowout coils *B*, B_1 and B_2 to assist in quickly interrupting the arc at the contactors. Coil B_1 is between the two contactors and is effective on whichever contactor is in use.

Assume that the car switch is closed to point 2 for up motion. Closing the 2 contact on the car switch completes the circuit through the coil of the up-direction switch *U*, from the + side

of the line to the throwover switch A and to 1 on the car switch. This part of the circuit is common to all four circuits made through the car switch. From 1 on the car switch the circuit is to 2 and to 2 on the top hoistway limit switches, returning to 8 at the

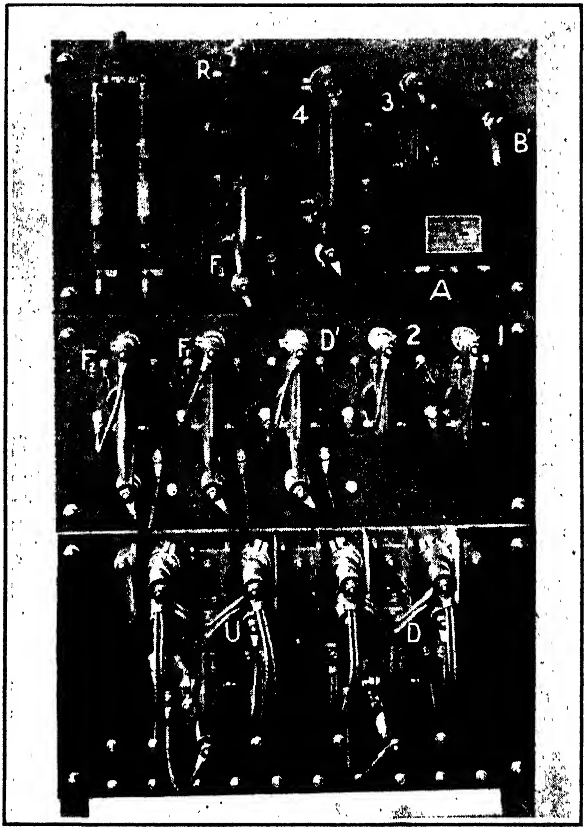


Fig. 151—Two-speed direct-current elevator controller.

U—Up-direction switch. D—Down-direction switch. Contactors 1, 2, 3 and 4 cut out the armature resistance. Contactors F_1, F_2 and F_3 cut in the field resistance. D'—Dynamic brake and non-interference magnet. R—High-speed relay. B—Control switch for operating elevator at slow speed from control panel. A—Switch to change from car-switch control to control on the panel board.

bottom of the controller, through the coil on the up-direction switch U, part of resistance R_d at the bottom of the contactor D' and to 6 at the bottom of the controller. From 6 at the bottom of the controller the circuit continues to 6 on the car-gate switch, through this switch and the safety and emergency switches and

back to 7 at the bottom of the controller and to the − side of the line. This circuit can be easily followed out on the simplified diagram, Fig. 153.

Energizing the coil on the up-direction switch causes this switch to close and completes the motor circuit. The armature circuit for the motor is from the + side of the line, through blowout coils B_1 and B, the top left-hand contact of switch U, through the coil on the overload relay OL, to A_1 on the motor. The circuit is then through the armature and back to A_2 on the controller, through all the starting resistance between A_2 and R, to the top right-hand contact on direction switch U and to the − side of the line.

The field circuit is completed from contact 12 on the up-direction switch to 12 on the motor through the field winding and back to 13 on the control board. If the inrush current through the overload relay OL is sufficient to close this relay and hold it closed, the shunt-field circuit is from 13 at the bottom of the controller through the overload relay and to the − side of the line. If the overload relay is open, the shunt-field circuit is from 13 at the bottom of the control panel, through the bottom contacts of field relays F_1, F_2 and F_3 to the − side of the line.

A circuit is provided for the brake coil from terminal 12 on the motor, through the brake coil to 10 at the bottom of the controller, through the bottom contact on contactor No. 4, to 10 on direction switch U, to the top right-hand contact of this switch and to the − side of the line. Energizing this circuit releases the brake and allows the motor to start.

Cutting Out the Starting Resistance.—The starting resistance is cut out of circuit by contactors 1, 2, 3 and 4. The coils of these contactors are in series and connected across the armature, so that their closing is controlled by the counter-electromotive force developed by the armature. A circuit for these coils is made from the left-hand side of the up-direction switch to a and through resistance R_a, coils 1, 2, 3 and 4 to A_2 on the starting resistance, through all the starting resistance to the right-hand side of the up-direction switch and the − side of the line.

One side of the armature is connected to the left-hand side of the reversing switch and the other to A_2 on the starting resistance. These are the two points to which coils 1, 2, 3 and 4 connect. Since these coils are connected across the armature, they will have a low voltage impressed on them at the instant of starting and will not close their contactors. As the armature increases in

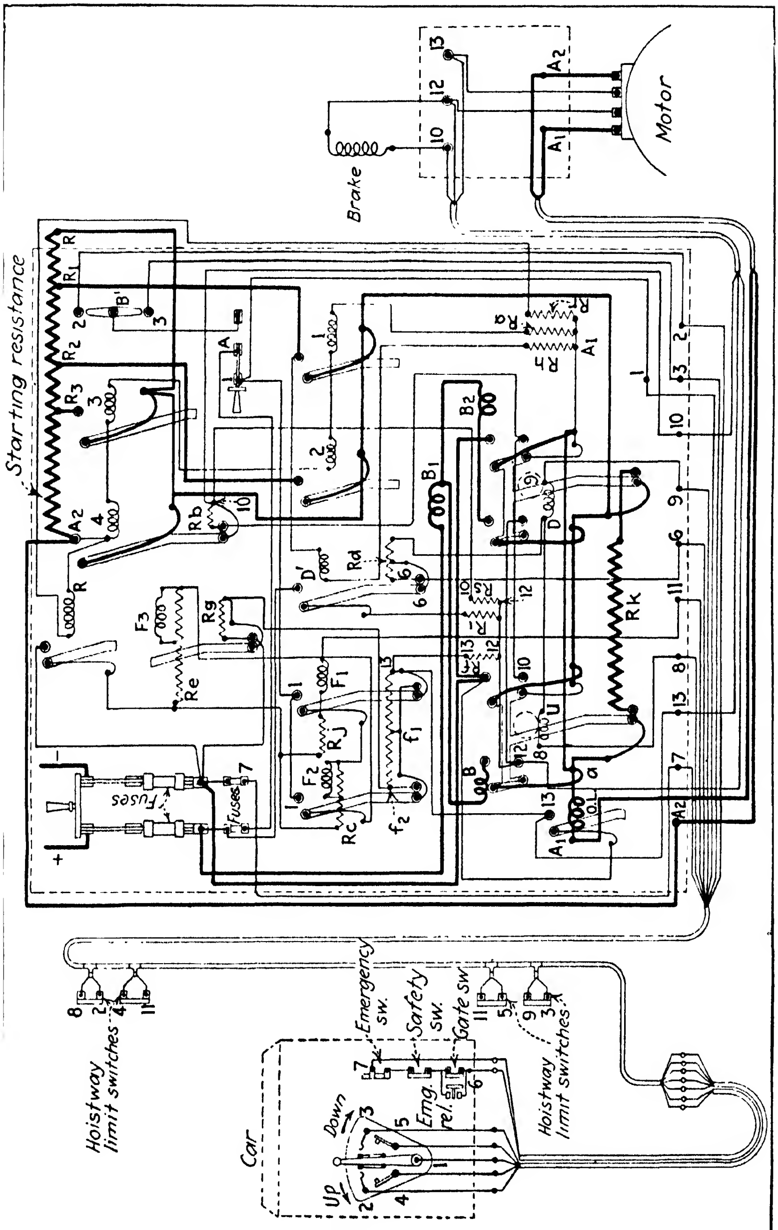


FIG. 152.—Wiring diagram for the controller Fig. 151.

speed, the voltage across its terminals increases, and when it reaches a certain value, the pull of coil No. 1 becomes sufficient to close its contactor.

Closing of contactor No. 1 connects R_1 on the starting resistance to the right-hand side of the up-direction switch and cuts out the section of resistance between R and R_1. This increases the speed of the motor and the voltage across its terminals, and the current in coils 1 to 4 reaches a value that causes No. 2 to close its contactor. Closing this contactor cuts out the section of resistance between R_2 and R_1, which further increases the speed of the motor and the voltage across the armature and causes coil 3 to close its contactor. This latter operation short-circuits the section of starting resistance between R_2 and R_3, which causes the speed of the motor to increase further and contactor 4 to close and connect A_2 on the starting resistance to the right-hand side of the up-direction switch. Therefore the closing of No. 4 contactor cuts all the starting resistance out of circuit, and the motor comes up to speed with the starting resistance cut out of circuit.

When contactor 4 closed, it opened its bottom contact and connected resistance R_b in series with the brake coil and reduced the current in this coil. Resistance R_s is connected from 12 on the left-hand side of the up-direction switch to 10 on resistance R_b. The brake coil also connects to these two points, therefore resistance R_s is in parallel with the brake coil. The function of this resistance is to cause a somewhat smoother application of the brake than would be the case if the coil circuit were opened when disconnected from the line. When the coil is disconnected from the line, its inductance sets up a current through resistance R_s. This current, which exists for a very short period, through the brake coil tends to retard its application and prevents mechanical shocks in stopping the car. Connecting a resistance in parallel with the brake coil also prevents a high voltage being induced in it when disconnected from the line.

High-speed Operation.—A circuit for relay R is provided from the left-hand side of the direction switch through resistance R_r, coil R to A_2 on the starting resistance. With the closing of contactor 4 a circuit is completed from A_2 to the $-$ side of the line for coil R, and this relay closes and establishes a circuit for the field contactors F_1, F_2 and F_3, when the car switch is closed to No. 4 or 5 contacts. Closing the car switch to the high-speed point 4, when relay R is closed, completes the circuit for the coil

of field contactor F_1, from 1 on the car switch to 4 and then to 4 and 11 on the top hoistway limit switches back to 11 on the control panel, through coil F_1 and the contact on relay R and to the minus side of the line. When contactor F_1 closes its top contact, it opens its bottom contact. The latter connects the resistance between 13 and f_1 in series with the field coils and causes an increase in speed.

Closing the top contact on switch F_1 completes the circuit for F_2 coil, from the throw-over switch A to the top contact of F_1 through coil F_2 and resistance R_c and to the $-$ side of the line. This will cause F_2 contactor to close and open its bottom contact, which will introduce the section of resistance between f_1 and f_2 into the field circuit, causing a further increase in speed. When the top contact of F_2 closed, it completed the circuit for F_3 coil and caused this contactor to function and open its bottom contact. Opening of the bottom contact of F_3 connected resistance R_g in series with the field coils and the motor now comes up to full speed.

It will be noted from the foregoing that the field resistance has been cut in by three steps. This gives a smoother acceleration than if it were all introduced in one step.

Controller Operation during Stopping.—The dynamic-brake contactor D' has its coil connected from the left-hand side of the up-direction switch, through resistance R_h to the top contact of contactor 1. When contactor 1 closes, its top contact is connected to the right-hand side of the up-direction switch and to the $-$ side of the line. Therefore when contactor 1 closes, in addition to cutting out a section of the starting resistance it also connects coil D' directly to the line and it closes its top contact. This provides a circuit for the field coils from the $+$ side of the line to the top contact of relay D', through resistance R_i and through the field coils back to 13 on the controller and to the $-$ side of the line. Consequently, as long as D' remains closed the field coils will be connected to the line through resistance R_i, no matter if the up-direction switch is open. The purpose of this circuit is to retain a magnetizing current in the field coils to cause the armature to produce a dynamic-brake action to assist in stopping the elevator.

Referring to coils F_2 and F_3, it will be seen that they are connected in parallel with part of resistance R_c and R_e respectively, while coil F_1 is connected in series with resistance R_f only. If all the coils were connected alike, the contactors would all open at

about the same time and the resistance would be cut out of the field coils in practically one step and cause an abrupt slow-down. The way the coils are connected to their resistances, contactor F_1 will open almost instantaneously when the car switch is moved off the high-speed point. When the coil circuit of F_2 is interrupted by opening the top contact of F_1, the current in the coil will not immediately decrease to zero. Owing to inductance a current will be maintained through the coil and the resistance connected to its terminals. This will cause a short delay in the opening of

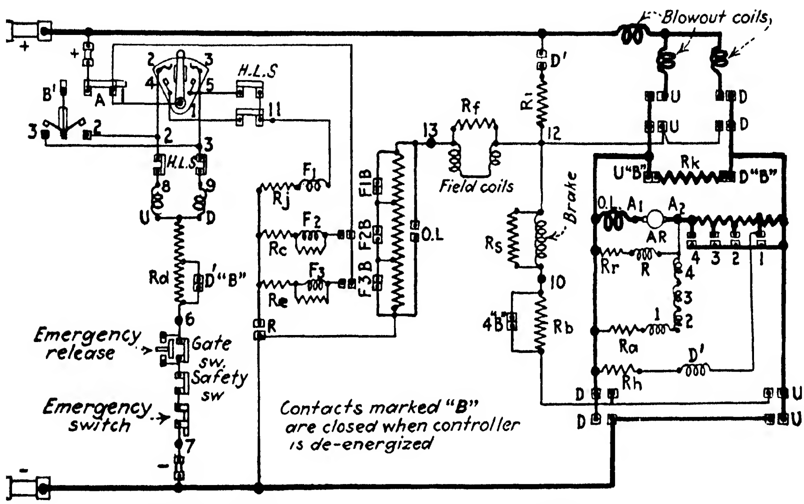


Fig. 153.—Simplified diagram of the connections shown in Fig. 152.

contactor F_2. A similar delay is caused in opening F_3, so that a gradual slowing down of the motor is obtained when stopping.

When the car switch is centered, the direction switch opens and then through the dynamic-brake action of the motor and the application of the mechanical brake the elevator is stopped. Opening of the up-direction switch connects resistance R_k between the bottom contacts of the two direction switches and completes a circuit for the armature, from A_1 on the motor to the bottom contact of the up-direction switch, through resistance R_k to A_2 on the starting resistance and back to A_2 on the motor. This circuit is on the assumption that contactors 1, 2, 3 and 4 have remained closed. As previously explained, the coils of contactors 1, 2, 3 and 4 are connected across the armature, therefore they will hold

their contactors closed until the armature has come down to a slow speed.

Contactor D' holds closed until the motor reaches a slow speed, and in addition to maintaining a current in the field coils for dynamic-braking action, also acts as a non-interference magnet. As long as the bottom contact of D' is open, all the resistance R_d is in series with the coils of the direction switches. Even if the car switch is moved to the on position, sufficient current cannot flow through the direction-switch coil to close it as long as all of R_d is in circuit. Contactor D' is so designed that it will hold closed until the motor has slowed down below where contactors 1 to 4 have opened. This arrangement prevents the operator in the car from suddenly reversing the motor before the starting resistance has been cut back into circuit.

When the overload relay *OL* is used, if a sustained overload is applied to the elevator, this relay will close and, as previously shown, short-circuit the field resistance. Therefore the motor can be operated at slow speeds only. The closing of this relay on the first inrush of current to the motor insures the motor's having full field at starting.

Resistance R_f is connected from 12 on the up-direction switch to 13 on the field resistance. These two points are the terminals of the field coils, consequently this resistance is connected in parallel with these coils. When inching the car to the floor or during similar movements, relay D' may not have time to close before the direction switch is opened, in which case the field circuit is broken. It is to prevent high voltages being induced in the field coil, under these conditions that resistance R_f is connected across the field coils. When the field circuit is broken, the induced voltage causes a current to flow through resistance R_f and prevents the voltage exceeding normal limits.

Stopping at Terminal Landings.—When stopping at the terminal landings, the hoistway limit switches function to stop the car similar to centering the car switch. First a cam on the car comes in contact with the first hoistway limit switch and opens it. Opening this switch performs the same function in slowing the car down, as moving the car switch off point 4. Further movement of the car opens the last hoistway limit switch, which has the same effect as centering the car switch, and the car comes to a stop.

In the foregoing the operation of the controller has been considered for only one direction of the car. The reverse motion is

the same as the up except that the down-direction switch *D* closes instead of the up-direction switch.

Extra Shunt-field Winding Used to Obtain Two Speeds.—Figure 154 shows an Otis type No. 3F full-magnet controller, which is one of the earlier types. With this type, high speed is

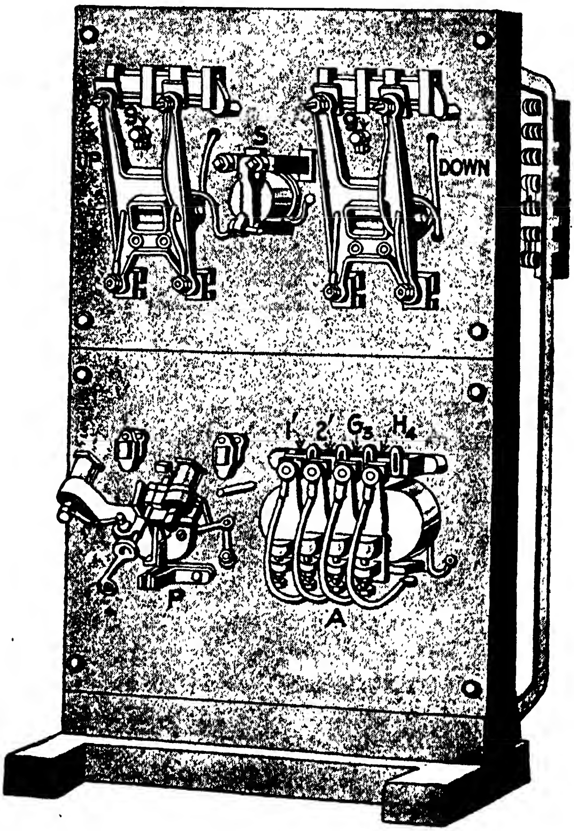


Fig. 154.—Control panel to obtain two speeds by using extra-shunt-field winding in the motor.

obtained by an extra shunt-field winding, shown in the connection diagram Fig. 155. This winding is cut out of circuit after the armature resistance and the series-field winding are. The direction switches on the controller are marked "Up" and "Down." The other switches on the controller are known as the potential or main-lines switch *P*, accelerating magnet switch *A*,

for cutting out the armature resistance, and the fast-speed magnet S.

The coil on the potential switch is in series with all the safety switches, therefore will drop out when any of the safety devices open. The reversing switches have an extra contact 9, which controls the brake circuit. The fast-speed magnet S is arranged with one contact arm that, when in its normal position, closes the circuit for the extra-shunt field on the motor and is controlled from the last points F_d and F_u on the car switch, Fig. 155. When this circuit is energized, the contact arm of the fast-speed magnet is drawn in and the extra-shunt-field-winding circuit is broken, which will cause the motor to attain high speed.

On the accelerating magnet there are four contact arms which are staggered so that each one is set a little farther from the coil than the preceding one, No. 1′ closing first and the others following in order. The accelerating coil is connected across the motor's armature so that, as the latter increases in speed and the voltage across its terminal increases, the current to the accelerating-magnet coil will also increase and close the contact arms one after the other. In this way the starting resistance and the series-field winding are cut out, after which the motor operates at full speed as a shunt machine.

The stop-motion switches, Fig. 155, are mounted above one of the drumshaft bearings, as at A Fig. 138, are operated by cams geared to a traveling nut on the end of the drumshaft, and are used to stop the car at the top and bottom landings. The stopping is accomplished by two contacts for either motion. When No. 1 switch opens, the circuit of the fast-speed magnet is broken, and the extra-shunt-field winding is again put into circuit, causing the motor to run at slow speed. When the contact on No. 2 cam opens, the magnet-coil circuit of the reversing switch is opened. This will allow the switch to drop out, thereby stopping the motor.

On the car switch, points D_0 and U control the magnet-coil circuits on the direction switches, and the points F_d and F_u control the circuit of the fast-speed magnet S. The car switch is connected by a flexible cable to a junction box located on the side of the elevator shaft, midway between the top and bottom, and from here the wiring is run in rigid conduits to the controller.

On a full-magnet controller there are two sets of circuits, the auxiliary and the power circuits. Both of these circuits are protected by fuses; and should a fuse blow in one or the other, the

motor will stop. The fuses protecting the auxiliary circuits are of small capacity, as these circuits require only a small amount of current to operate the various elements. The power circuits are protected by fuses heavy enough to carry about 50 per cent more than the full-load-current rating of the motor.

The auxiliary circuits consist of all the wiring for the magnet coils of the reversing switches, the fast-speed magnet, the no-voltage release coil on the potential switch, the upper- and lower-limit switches, the governor and the slack-cable switches, and the safety switch in the car. The power circuit consists of the motor circuits—that is, the armature, shunt, series and extra-shunt field. With the exception of the shunt-field winding, all the power circuits are shown in heavy lines on the diagrams, and the auxiliary circuits in light lines.

Potential-switch Circuit.—Figure 155 shows the wiring diagram with the car switch in the slow up-direction position and the up-direction switch and potential switch closed on the controller. The potential-switch circuit is from a on the positive side of the potential switch to the small fuse F', up to terminal $+0$, then to the hatchway-limit switches, and back to $+P$ on the controller, down through the potential-switch coil PC to terminal $-P$, through the slack-cable, the safety switch in the car, through fuse F'' and to terminal H on the controller, to H_4 on the accelerating magnet, and to the negative side of the line as indicated by the arrow-heads. This circuit energizes the potential-switch coil and holds the switch closed.

Direction-switch Circuits.—When the operator throws the car switch on the slow up-motion position, current will flow from a terminal on the positive side of the potential switch to Y, where the circuit divides. One path is through the safety devices and potential switch, the other through magnet coil L on the up-motion reversing switch to terminal U' on the board. From here to U' on the stop-motion switch, all contacts being closed, the current passes to U on the car switch. From this point to the switch lever, which makes contact between U and $-C$, from $-C$ to the bridge connecting the blades of the safety switch to -0 on this switch, back to terminal -0 on the control board, and to the negative side of the line. Energizing the coil on the up-motion reversing switch causes the latter to close, which makes contact between contacts 1 and 3, also 4, 9 and 2, and opens contacts 5 and 7, 6 and 8, as shown.

Circuits Made by Up-motion Switch.—The closing of the up-motion switch completes five circuits—namely, the armature, which includes the series-field, the shunt-field, extra-shunt-field,

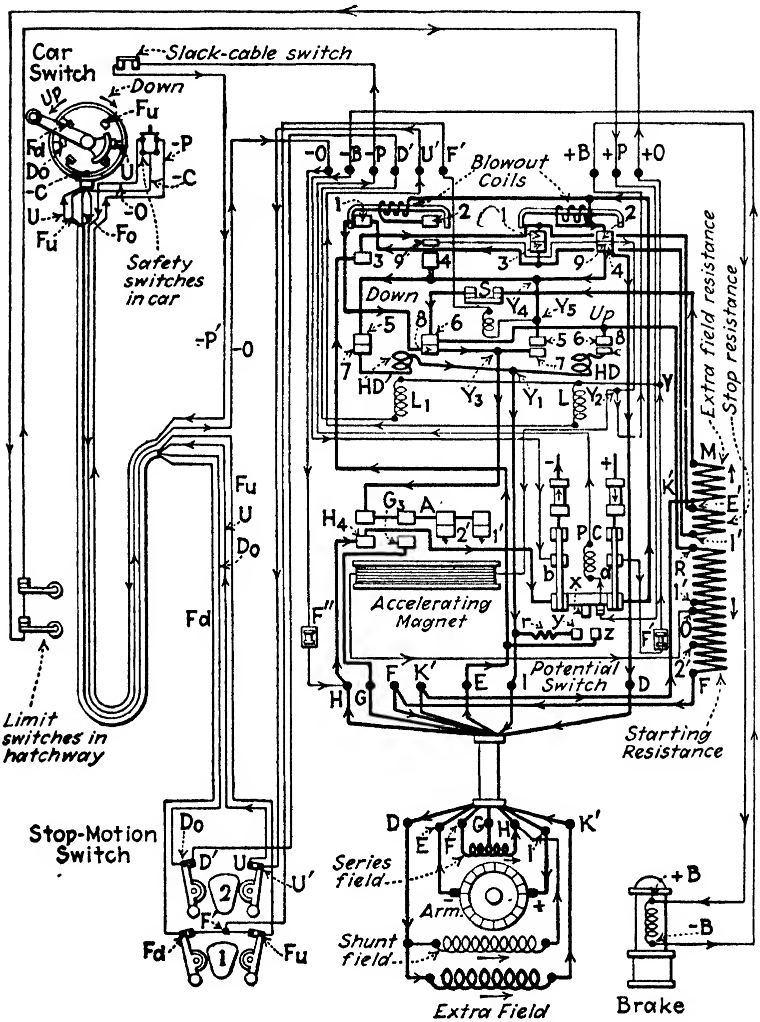


Fig. 155.—Wiring diagram for control panel, Fig. 154.

accelerating-magnet and the brake-coil circuits. The direction of the flow of current is from the bottom terminal on the positive side of the potential switch to the blowout coil on the up-motion

switch, through this coil to contacts 2, 9 and 4; from contact 4 to contacts 5 and 7 on the down-motion switch, and then through the hold-down coil HD' to point Y_1, then down to terminal I on the control board, and from here to one side of the armature, through the armature to terminal E and up to contact 3 on the down-motion switch to No. 1 and 3 on the up-motion switch, and back to 1 on the down-motion switch, then to 8 and 6, also on the down-motion switch, to R on the starting resistance, through this resistance to terminal F on the control board, which leads to one side of the series field; through the series-field winding to terminal H on the control board, to contact H_4 on the accelerating magnet, and to the negative side of the potential switch.

The shunt- and extra-shunt-field circuits are from contact 4 on the up-motion switch to terminal D on the controller board, down to one side of the shunt and extra-shunt field, where it divides, one circuit being through the shunt field to terminal H, from there to contact H_4 and back to the negative side of the line. The other circuit is through the extra-shunt-field winding to terminal K', from here to K' on the control board and to the extra-shunt-field resistance; through this resistance to M and to the fast-speed magnet S; from here to contact 6 on the down-motion switch and to R on the starting resistance. Through this resistance to F on the control board, and through the series-field winding to H_4 and back to the negative side of the line.

The accelerating-magnet circuit starts from contact 9 on the up-motion switch, down to point Y_2. At this point the accelerating-magnet and brake-coil circuits divide. The accelerating-magnet circuit passes to the accelerating coil, through this coil to point O on the starting resistance, through the lower portion of this resistance to terminal F, which leads through the series field to terminals H and H_4, back to the negative side of the line. The brake-coil circuit is from point Y_2 to terminal $+B$ and then through the brake-magnet coil, back to terminal $-B$ to the negative side of the line at b.

With these circuits closed, the motor should start and increase in speed. This will increase the voltage across the armature and strengthen the accelerating magnet, which will first close contact No. 1′ and then No. 2′. These two contacts cut out nearly all the starting resistance, and the motor will then run at practically full speed with all the field windings in circuit. The direction of the armature current is now from contacts 6 and 8 on the down-

motion switch to Y_3 where it takes the easier path down to the accelerating magnet, to contact point 2′ on the starting resistance, through the motor to the negative side of the line.

With contacts on No. 1′ and 2′ closed, the voltage across the armature is increased again, which increases the pull of the accelerating-magnet coil and causes contacts G_3 and H_4 to close, cutting out the remainder of the starting resistance and the series field winding in two steps. Contact G_3 cuts out one-half the series field and the remainder of the starting resistance, and H_4 cuts out the last half of the series field. This brings the motor up to full speed as a shunt machine. The direction of the current through the motor is now from Y_3 connection to H_4 on the accelerating magnet, and then directly to the negative side of the line. The motor is now running as a shunt machine with the extra-shunt field at maximum strength. At starting, the armature starting resistance was not only in series with the armature, but also with the extra-shunt field. Therefore, by cutting out this resistance and series-field winding, the voltage is not only increased across the armature, but the extra-shunt-field current is also increased. Consequently, the increase in speed will not be so great as when this condition did not exist.

High-speed Control Circuit.—To increase the speed further, the operator places the car switch on point F_u. This establishes a circuit from 4 to Y_5, through the fast-speed magnet coil to F' at the top of the control board, down to F_u contactor on stop-motion switch No. 1; from here to F_u on the car-operating switch, then to $-C$ on the safety switch in the car, around to $-O$ at the top of the control board, to the negative side of the line. Energizing the fast-speed magnet coil will cause it to open contactor S and cut out the extra-shunt-field winding. When this field winding is cut out, the field strength of the motor is considerably decreased and the motor comes up to full speed.

Assuming that the car is about to reach the upper landing and the operator keeps the car-switch handle on the fast-speed contact F_u, in such a case the traveling limit nut on the drumshaft will come into action and turn cam No. 1 to open contact F_u and open the high-speed magnet-coil circuit, causing the extra field winding to be cut back into circuit and slow the machine down. As the car about reaches the top landing, cam No. 2 of the stop-motion switch opens contact U'. This breaks the circuit of the magnet coil of the up-motion switch, which drops out, breaking

contacts 1 and 2, also 3, 9 and 4, and closes the bottom contacts 5 and 7, 6 and 8. The opening of this switch opens the entire circuit of the motor and releases the brake shoes, which are set by spiral springs.

When the up-motion switch opens and closes contacts 5 and 7, 6 and 8, they connect the armature through the resistance $E'I'$ and a dynamic-braking action takes place. As long as the armature continues to revolve and a field is maintained, a current will flow. This circuit is from the + brush on the armature to I on the control board to contact 8 on the up-motion switch, around to 6 and then to 1 on the down-motion switch, to I' on the stop resistance, through this resistance to E' back to contact 3 on the down-motion switch, to terminal E at the bottom of the control board and back to the negative side of the armature. This dynamic-braking action assists the mechanical brake to bring the car quickly and smoothly to a stop at the landing.

Should anything go wrong with the auxiliary circuit, the potential switch will open and contact arm x will close contacts y and z. This short-circuits the armature through the resistance r, causing a dynamic-braking action, since y and z are connected to the armature terminals, which will assist in stopping the machine.

CHAPTER X

DIRECT-CURRENT HIGH-SPEED TRACTION-MACHINE RHEOSTATIC CONTROLLERS[1]

Traction Elevator Machines.—Traction elevator machines, one type of which is shown in Fig. 156, have within the last few years come into very general use and to a large extent have superseded the drum-type machine. The control for traction machines offers special problems, and a wide variety of controllers have been developed for this class of equipment. A front view of an Otis Elevator Company's type MF-4-B controller is shown in Fig. 157 and a diagram of the connections in Fig. 158. Although this type is not one of the latest built by this company, it is representative of a type that has a wide use.

The main line or potential switch A in the figures carries the current for all parts of the elevator mechanism except the motor field coils and the holding coil A_c on the switch. Holding coil A_c is energized by a circuit from the positive main, through fuse F_1, contact H' of magnet H, safety switch N in the car, switch M, which is mounted on the safety plank under the car and opens when the safeties are set. From switch M the circuit is through contact G' on the governor, upper contacts of hatchway switch I_h, lower contacts of hatchway switch E_h, coil A_c on the potential switch A, upper contacts of hatchway switch E_h, lower contacts of hatchway switch I_h to switch P on the controller and the negative side of the line. A simplified diagram of this circuit is shown in Fig. 159.

Stopping Circuits.—If the circuit through coil A_c of the main-line switch A is broken, the switch will open and the feed wires to the motor will be interrupted and the motor stopped when any of the following contacts are separated:

1. Contacts H' of switch H. The coil of this switch is in series with the motor's field winding and contact H' are held closed as

[1] Warren Hilleary, Superintendent, Royal Indemnity Co., and William Zepernick, Otis Elevator Co., supplied a large part of the material in this chapter.

long as the field circuit is energized. Opening of the field circuit allows contact H' to open, which in turn causes potential switch A to open and stop the motor.

2. Contacts of switch N. This switch is a safety device placed close to the control switch in the car. In case of emergency the elevator operator may open it and thus cause the potential switch to open.

3. Contacts of switch M. This switch is placed on the bottom of the car and is operated when the car safeties are applied.

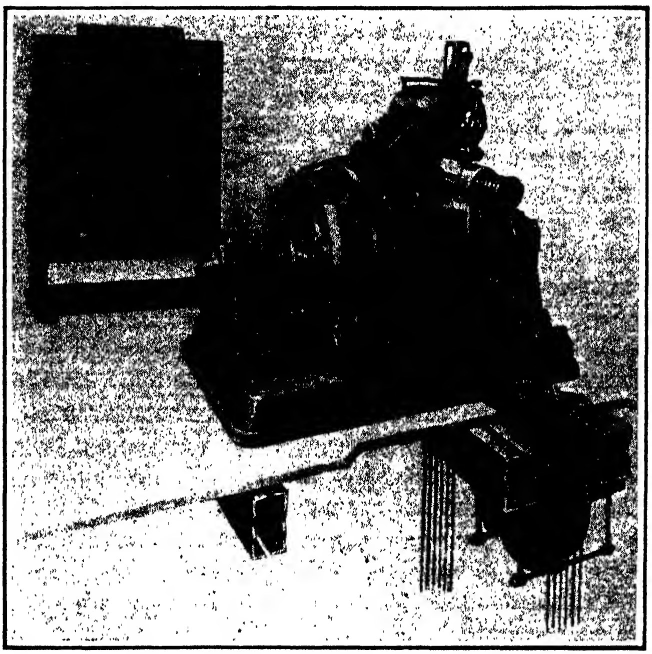


FIG. 156.—Direct-type traction elevator machine.

4. Governor contacts G'. The governor has two fixed contacts and two movable contacts. When the car speed increases above normal, first contacts G'' close, thus short-circuiting part of the shunt-field resistance R_s, which should slow down the machine. If the speed keeps on increasing, contacts G' break the circuit through the coil of the main-line switch A and stop the machine.

5. The contacts of hatchway switches I_h and E_h, operated by a cam attached to the car, limit the travel of the car at the terminal landings. Under normal conditions the elevator will auto-

matically come to a stop when the cam on the car opens switch K_h, at the top or D_h at the bottom. If, however, for some reason motion continues, the opening of the contacts of switches I_h or E_h will open the main switch A and at the same time contacts A' and A'' will be closed, causing a strong dynamic-braking effect by short-circuiting the armature through a section Y of the armature shunt resistance.

Reversing Switches Have Two Coils.—Each of the reverse switches B and C has two coils B' and B'' and C' and C'' respectively. The lower coils are connected shunt and the upper coils are in series with the armature. The shunt and series coils work in opposition to each other, having, however, separate paths for the two magnetic fluxes. When the shunt coil B' of switch B is energized, top contacts B_1 close and bottom contacts B_2 open. This completes the armature circuit from the positive line terminal through contacts A_1 of potential switch A, contacts B_1 on reversing switch B, left-hand contact C_2 of switch C, series coils B'' and C'' of switches B and C, through the armature and series starting resistance R_2 right-hand contacts C_2 of reversing switch C, through series starting resistance R_1, contacts A_2 on the potential switch and to the negative side of the line. At the same time a circuit parallel with the armature is made, branching off at Z and through a section of the armature shunt resistance between 8 and 9 to contact G_a through the top half of the contacts of switches F, E and D to X and through series starting resistance R_2 to the negative side of the line as did the armature current. The effect of this parallel resistance is to give a very slow speed.

The effect of the series coils B'' and C'' on reverse switches B and C is as follows:

Suppose the shunt coil of B to have been energized and as a consequence its top contacts closed and its lower contacts opened. On account of the motion of the magnet plunger to its extreme position under the influence of the shunt coil, the energizing of its series coil, which occurs a little later with the closing of the armature circuit, has little effect in opposing the shunt coil. However, as switch C remains in the off position without excitation in its shunt coil, its plunger remains in such a position that the flux generated by its series coil has maximum effect tending to press contacts C_2 tightly together. When the elevator is stopped, current through the shunt coil of switch B is interrupted, but the current through the switch's series coil is not broken until a

moment later when the top contacts open, therefore the effort of the series coil assists the weight of the switch armature to return to its off position, thereby securing a quick break of the top contacts. For the reason that the top contacts of the reversing switches *B* and *C* make and break the main current, they are arranged two in parallel.

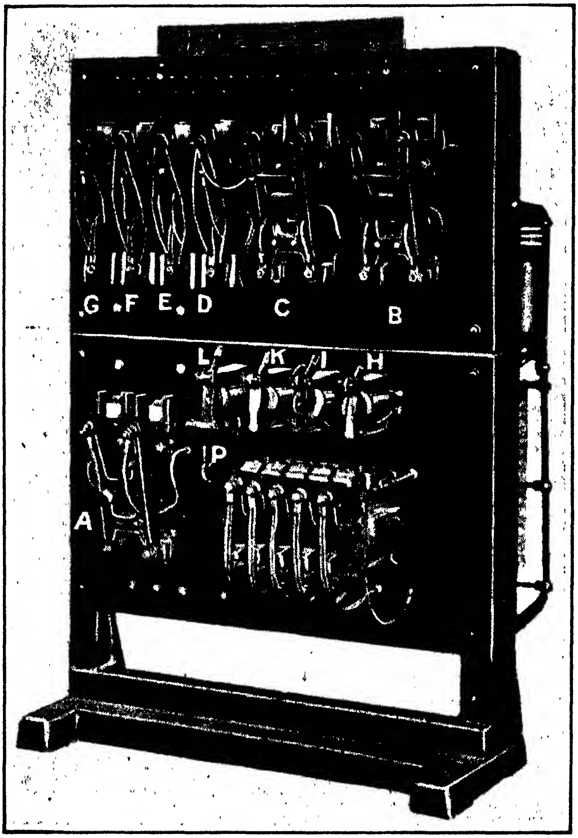


FIG. 157.—Front view of an Otis type MF-4-B controller for a traction elevator.

Brake Controlled by Reversing Switches.—The reversing switches also control the brake which is kept normally on by springs. When, for instance, switch *B* closes, contacts B_3 make and B_4 break. The brake-coil circuit is from the positive terminal of the potential switch through contact A_3 on this switch, contacts B_3 of reversing switch *B*, contacts B_c of a switch mechani-

cally operated by the brake magnet, through the brake coil to contact A_4 of the main-line switch to the negative terminal of the line. As a consequence the brake is released and opens contacts B_c, which connects resistance R_b in series with the brake coil, thus reducing the current in the coil and preventing overheating. At the same time resistance R_p remains in parallel with the brake coil.

When switch B drops out, the current through the brake coil is interrupted, but a self-induced current is maintained through resistance R_p, with the tendency to retain the brake released. When finally switch B returns to its off position, contacts B_4 make and parallel resistance R_p with resistance R_s and R_b in series with the effect of maintaining the current through the coil. The current quickly weakens to the point where the brake-coil plungers separate and allow the brake to set, but shortly before this takes place contacts B_c close again, thus cutting out resistance R_b. This practically short-circuits the brake coil as resistance R_s is low. The result is a tendency to maintain the induced current in the brake coil, which exercises a retarding effect on the magnet cores, so that the brake shoes are gently applied to the brake pulley. By means of resistances R_p and R_s the time lag between the interruption of the brake-coil current and the setting of the brake may be regulated within limits.

Switch C is identical in its functions with switch B, except that B controls the down motion of the car, while C controls the up motion.

Speed-magnet Switches.—Switches D, E, F and G are controlled by the car switch. Switch G is designed to operate first, closing contacts G_s, cutting out section 1 to 2 of series starting resistance R_2 and opening contacts G_a, thereby inserting the portion 9 to 10 of the armature shunt resistance in the circuit across the armature. The closing of contactor G also closes the secondary contacts S_1 which are part of the circuit of the coil of switch F, so that F cannot be energized unless switch G has closed. When F operates, the closure of contacts F_s short-circuits all of series starting resistance R_2 and the opening of contacts F_a inserts portion 10 to 11 of the armature shunt resistance across the armature. The closure of secondary contact S_2, which is part of the energizing circuit of switch E, permits the operation of this switch only when F has closed, except under certain special conditions, which are discussed later.

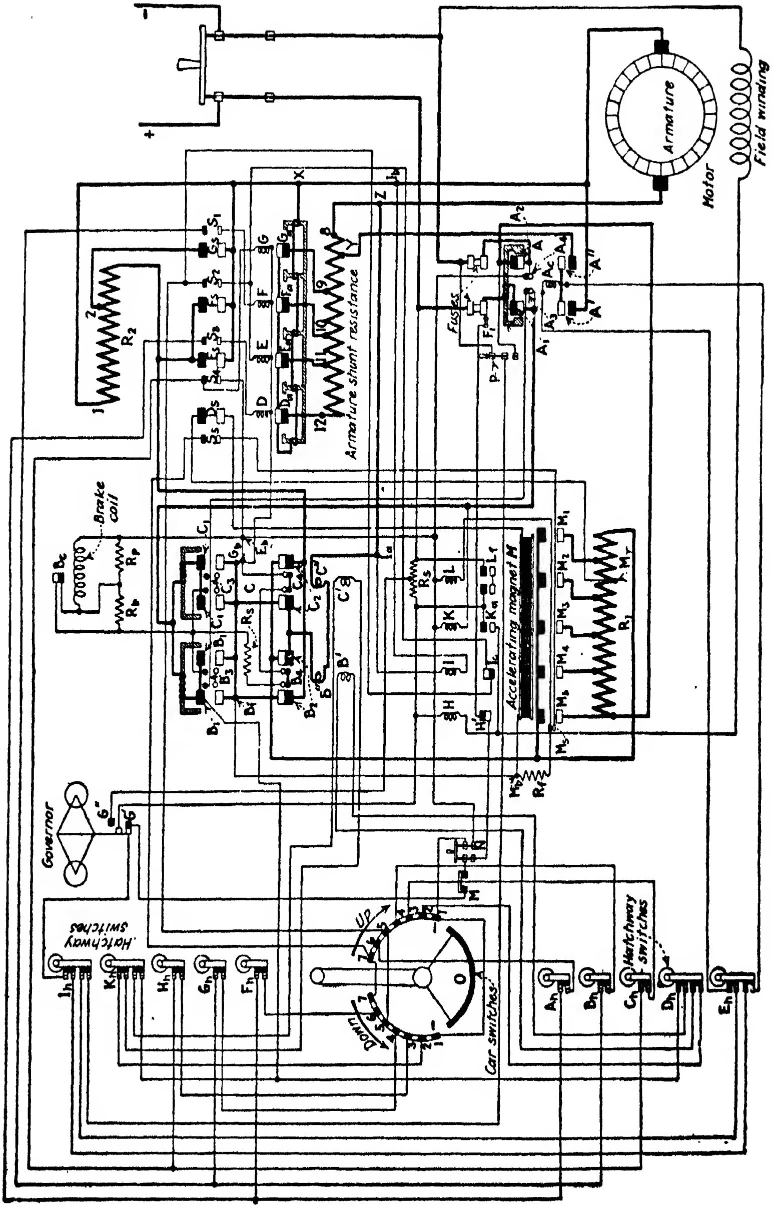


FIG. 158.—Diagram of connections for the controller shown in Fig. 157.

The closing of contacts E_s through the operation of switch E has no effect, these contacts being in parallel with F_s. The opening of contact E_a inserts additional resistance in the armature shunt resistance circuit. The right-hand secondary contact S_3 of switch E is to prevent the energizing of D unless E has operated. The purpose of the left-hand secondary contact S_4 is indicated later in a description of magnet I.

The operation of switch D opens contact D_a, thereby opening the armature shunt-resistance circuit. It also closes contacts D_s, thus closing the circuit of the accelerating magnet M, while the secondary contact S_5 allows the insertion of resistance into the shunt-field circuit by the master controller.

Fast- and slow-speed switch L is energized simultaneously with the closing of the armature circuits and receives current from left-hand B_1 contacts at B_f on the reversing switch through resistance R_f, through coil L, to A_4 on the potential switch and to the negative side of the line. As a consequence contacts L_f close and short circuit the shunt-field resistance R_s and permit the motor to start with maximum field strength.

Operation of the Accelerating Switch.—Accelerating magnet M automatically controls series starting resistance R_1 and comprises five switches, each having its own magnetic circuit but all energized by a single coil. This coil is energized when switch D closes contact D_s, the circuit being from M_b, through the accelerating-magnet coil M, contact D_s of switch D, and point M_r on the series starting resistance. Coil M is, as may be seen, in parallel with the armature, and subject to its counter-electromotive force. The switches are adjusted so that, at a certain counter-electromotive force, contact M_1 operates and as the motor accelerates M_2, M_3, M_4 and M_5 close, each successively cutting out a step of the series starting resistance. On the operation of M_5 all the starting resistance is cut out and at the same time the secondary contact M_s is made, which short-circuits coil L, inasmuch as the current, which originally passed through coil L, will be diverted to go from M_s to contacts S_5 on switch D, contact 7 of the car switch through the right-hand side of emergency switch N and to the negative side of the line, in case the car switch is in either of its extreme positions. With these conditions the machine runs at maximum speed. The accelerating magnet M cannot be energized unless switch D has operated. This safety feature prevents the cutting out of the series resistance and plac-

ing the motor directly across the line, before the armature-shunt resistance is opened.

Load switch I is in parallel with the armature, being connected to the armature wires at I_a and I_b. It is, therefore, subject to the motor's counter-electromotive force and will not open its contact I_c unless the motor has attained a certain speed. If the motor speed drops below a fixed minimum, the switch will drop out and close contact I_c again. The functions of this switch will be explained later.

Safety switch H is in series with the shunt field and, as explained previously, will open its contact H' in case of failure of the shunt-field current. The opening of contact H' results in opening the potential switch and stopping the machine.

Switch K is connected directly across the line. In case of excessive potential (20 per cent above normal) it operates, closing

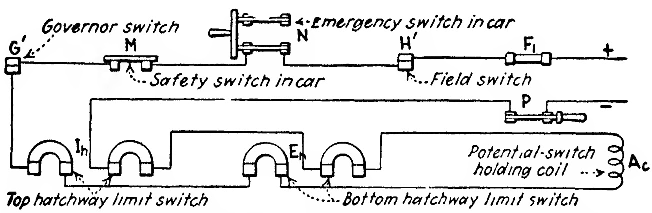


FIG. 159.—Simplified diagram of potential switch holding-coil circuit.

contacts K_a and short-circuiting magnet H. The latter opens its contact H', stopping the machine in the manner previously described.

With the single-pole knife switch P closed to the up position as in the figure, the potential switch A will close automatically whenever the holding coil's circuit is complete. With switch P closed to the down position, the potential switch must be closed by hand after it has once opened, but coil A_c will hold the switch closed after it has been closed by hand.

Operation of the Elevator from the Car Switch.—With the functions of the several magnets explained, the operation of the elevator by means of the car switch is as follows: Contacts 1 of the car switch are connected to the negative side of the line through the right-hand side of the emergency switch N, contact A_4 on the potential switch A to the negative side of the line. By moving the car-switch handle, for instance, in the direction of the down arrow, contacts 2. 3. 4, 5, 6 and 7 at the right are successively con-

nected with contact 1, through segment O. The current's path may be traced from the positive side of the line to these contacts. Thus when contact O engages points 1 and 2, the path of the current will be from upper contact B_1 on reversing B, which connects to the positive side of the line, to the upper contacts of hatchway switch D_h, shunt coil B' of reversing switch B back to lower contacts of hatchway switch D_h, thence to contacts 2 and 1 on the car switch and to the negative side of the line. This energizes coil B' of switch B, which in operating makes the motor connections and lifts the brake shoes as previously described.

Further motion of the car switch brings contactor O in connection with point 3, and the circuit may be traced from the lower side of the upper contacts on the reversing switches B and C, which, upon the operation of either reversing switch, is in connection with the positive terminal. Starting from G_b, the circuit is through coil G to the upper side of S_4, to hatchway switch C_h, to 3 on the car switch and to the negative side of the line. The operation of switch G cuts out a step of the armature series starting resistance and inserts additional resistance in the armature shunt resistance, thereby speeding up the motor. In the same manner another increase occurs, when F is energized following the closing of point 4 by the car switch. This circuit is from G_b through coil F, contact S_1 hatchway switch B_h to 4 on the car switch and to the negative side of the line.

When the car switch makes contact at point 5, the connections result in providing a circuit to energize the coil of speed switch E, with a corresponding increase in the elevator speed. In this case the current does not go through any of the hatchway switches, but is direct from G_b through coil E and contact S_2 to 5 on the car switch and the negative side of the line.

Switch D is energized when the car switch is moved to make contact at point 6. The path of the current is through coil D, contact S_3, hatchway switch A_h and to 6 on the car switch. With the operation of switch D, the armature shunt resistance is opened, the accelerating magnet M is placed across the armature and a further acceleration occurs automatically through the gradual cutting out of series starting resistance R_1. Finally, with the car switch in the extreme position segment O makes contact with point 7, thus short-circuiting, in the manner already explained, fast- and slow-speed magnet L, which in dropping out inserts the resistance R_s in the shunt field and brings the motor to full speed.

The current in this circuit also does not pass through the hatchway switches. Moving the car-switch handle in the direction of the up arrow, causes the magnets to act in the same manner, except that reversing switch C instead of B operates, causing the motor to run in the opposite direction. Also it will be seen that the current operating switches C, G, F and D in this case have their paths over the upper hatchway switches K_h, H_h, G_h and F_h.

In stopping at the floors, the car-switch handle is placed in the central position and the switches return to their off position in the reverse order from which they operated at starting. All elevators are provided with a device that brings the machine automatically to rest at the upper and lower terminal landings, independent of the operating device.

Control of Car at Terminal Landings.—Suppose the elevator is going down and the operator retains the car switch in the full-speed down position; a cam on the car will, when near the bottom landing, successively open the lower group of the hatchway switches, with the following results: The breaking of the contacts of switch A_h drops magnet D. The opening of its contacts D_s and S_5 results in the interrupting of the circuit through accelerating magnet M and inserting series starting resistance R_1. The short-circuit around the fast- and slow-speed magnet L is also opened by opening contacts M_s of the accelerating switch. Coil L again becomes energized and in attracting its armature makes contacts L_f and short-circuits the field resistance R_s. The making of contact D_a on switch D re-establishes the armature-shunt resistance 8 to 12, and the effect of the three operations slows down the motor. A little later the cam on the car opens the contacts of hatchway switch B_h, dropping switch F. Since the secondary contacts S_2 of this switch control switch E, under ordinary circumstances E will drop also. The result is that a portion of series starting resistance R_2 is added to the armature circuit, and the closing of the bottom contacts F_a and E_a short-circuits the portion between 10 and 12 of the armature-shunt resistance, thereby exercising a considerable slowing-down effect. The opening of the contacts of hatchway switch C_h drops switch G, with the result that with the breaking of its top contacts G_s, the entire series resistance is placed in the armature circuit, while the making of contact G_a reduces the armature shunt resistance to the portion between 8 and 9.

Opening the Direction Switches.—Further motion of the car causes the cam to engage hatchway switch D_h, which drops reversing switch B, breaking the armature circuit and leaving the motor subject to the dynamic-brake action due to the shunt across the armature with resistance R_2 in parallel with the section 8 to 9 of the armature shunt resistance. A little later, owing to the lag between the action of reversing switch and brake, the brake sets and the elevator, under ordinary circumstances, stops. However, should for some reason its motion continue, the opening of hatchway switch E_h occurs, followed by the opening of potential switch A, which in making its lower contacts A' and A'' reduces the armature shunt resistance to the portion between 8 and Y, thereby exercising a heavy dynamic-braking effect.

If the elevator still continues to travel, it will engage the buffer under the car, relieving the traction of the cables on the motor sheave, thus stopping the car. It will be noticed that the hatchway switches, which slow down the elevator, namely, A_h, B_h and C_h at the bottom and F_h and G_h and H_h at the top, have double contacts, while those more important in stopping the motor, namely, D_h, E_h and K_h, I_h, at the bottom and the top of the hatchway respectively, break the circuit at four points.

The series-starting resistance is not proportioned to the maximum elevator load but to the average. That is, the two parts of the starting resistance in series will admit sufficient current to the motor to start an average load, but the maximum load can be started only when R_2 is cut out. For this reason the series starting resistance is split in two parts, of which one is under control of the operator. When the car reaches the terminal landing and opens the several hatchway switches, all the magnet switches successively drop into their off position, beyond the further control of the operator, and insert resistance in the armature circuit as outlined in the foregoing. This might stop the car with a heavy load before the top terminal landing is reached or before the bottom landing is reached with a light load in the car, if a means were not provided to prevent the motor from slowing down below a certain limit when the car successively engages the hatchway switches. If the car slows down below that limit, switch I, whose coil is energized by the armature's counter-electromotive force, drops out, permitting contacts I_c to close.

Stopping with a Light Load in the Car.—Consider the case of a light load on the motor, the operator retaining the master switch

in the full-down position and the cam on the car striking the lower hatchway switches: First, the opening of hatchway switch A_h opens switch D, the opening of B_h opens F, and when the load is average, E also opens, owing to the opening of the secondary contact S_2. If the load is light the resulting slow-down due to the over-counterweight is too much, causing the load magnet I to drop out and close contact I_c. This results in bypassing contacts S_2 so that E will remain energized by a circuit from G_b through coil E to contact I_c, then to 5 on the car switch and to the negative side of the line. With a light load, therefore, E remains energized and its secondary contacts S_4 stay closed, which allows magnet G to receive current from G_b through coil G, secondary contact S_4 of switch E to E_b and to the negative side of the potential switch. Therefore when the cam on the car engages hatchway switch C_h in case of a light load in the down motion, switch G remains closed, so that, of the 4 switches D, E, F and G, D and F drop out and E and G stay closed. The result is that all the series starting resistance R_2 remains cut out, with the resistance of 8 to 10 shunted across the armature, whereby sufficient potential and current is supplied to the motor to prevent stalling or undue slowing down. In the up motion with a heavy load, the same operations would take place on approaching the top landing, as explained for the car with a light load approaching the bottom landing.

Six-speed Type Controller.—Otis Elevator Co., type (MFL4C) controller is shown in Fig. 160. The principal features of this controller may be outlined as follows:

With the car switch, Fig. 161, six distinct speeds, up and down, are obtainable which are: Direction, fast 1, 2, 3, 4 and 5 respectively. At the terminal landings cams are installed in the hatchway which engage a roller secured to an arm on the stopping switch, Fig. 162, mounted on the hitch beam, on top of the car. Operation of the stopping switch opens a series of contacts which reduce the speed in four steps and then stops the elevator by releasing the direction switch. The setting of the automatic stopping switch on top of the car is such that the speed switches drop out in the reverse order to that in which they pull in. There are seven contacts for each direction on the automatic stopping switch, as shown in the upper left-hand corner, Fig. 163, and the last three contacts, Nos. 5, 6 and 7, open simultaneously. Nos. 5 and 6 each open one side of the direction magnet, and No. 7

opens the circuit which parallels the brake magnet providing for a quick release of the brake at the terminals.

In addition to the circuits controlled by the automatic stopping switch, there are the final limit switches for overtravel at the terminals, the switch in the car for emergency, safety-plank switch under the car, which opens when the safeties are set by action of

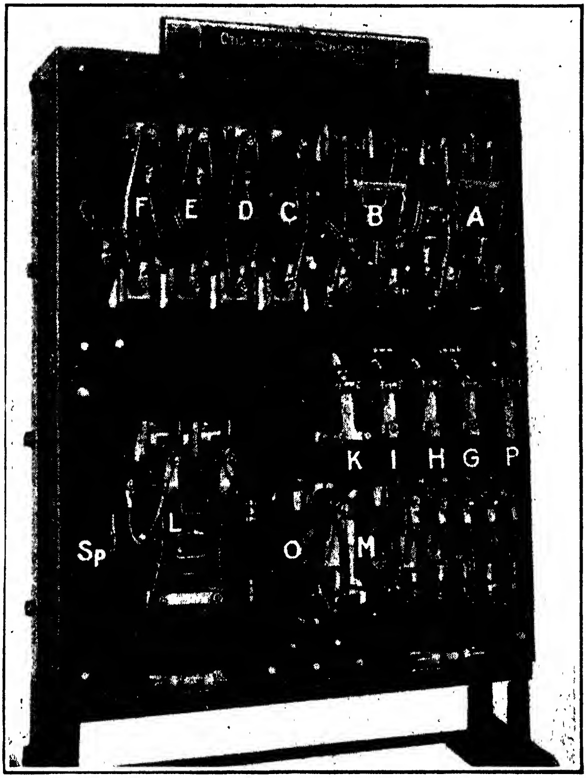


FIG. 160.—Front view of Otis type MFL4C controller for gearless traction elevator machines.

the governor, and a governor switch for overspeeding. Any of these will release the potential switch, which will open the power line to the machine and brake circuit and apply a hard dynamic brake by means of connecting resistance across the armature.

Controller Circuits.—The wiring diagram, Fig. 163, is an outline of the controller, Fig. 160, looking at the panel from the rear. The contacts are shown in a position assumed with the main

switch open. As each switch operates, the contacts shown open are closed and those that are closed immediately open. With all emergency switches closed the elevator may be operated on any

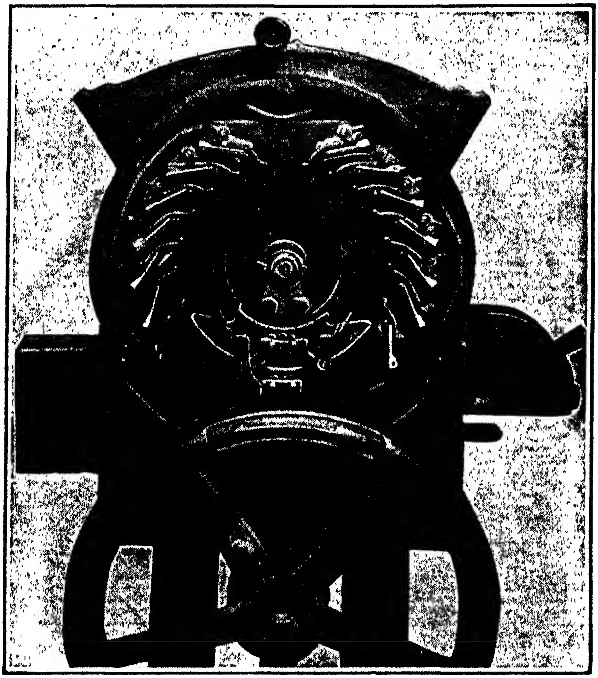


Fig. 161.—Car switch with cover removed.

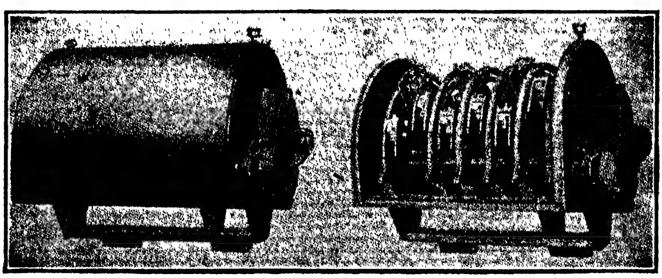


Fig. 162.—Stopping switch located on top of car.

speed by moving the car switch to any desired position. The car switch is generally wired so that moving its handle away from the side of the hatch that has the most openings will cause the elevator to run up, the other way for the down direction of travel.

When the main-line switch is closed, as in the wiring diagram, Fig. 163, the shunt-field circuit is immediately energized, which provides a positive field on the motor at the instant of starting. This circuit is from the + to the D terminal at the bottom of the controller, through the shunt-field winding on the motor to the K terminal on the controller, through the SFR resistance to the − terminal on the potential switch L and to the − terminal at the bottom of the controller.

Potential-switch Coil Circuit.—After the main-line switch is closed, if all emergency devices such as governor switch, final limits, safety-plank switch, emergency switch in the car, etc., are closed, the potential switch will close. All emergency switches with the exception of the last-named are normally closed, since these open only when called upon by overspeeding of the car, overtravel at the terminal landings, etc. The emergency switch is operated at will by the operator and is generally opened when the operator leaves his car.

The top main contacts, M_a, of the potential switch, close to the main-line circuit to the controller. These contacts are equipped with blowout coils to prevent arcing. The auxiliary contacts A_c complete the line to the various operating and brake circuits. The bottom main contacts M_b are utilized to connect the section of bypass resistance between E' and I across the armature to insure a quick stop should the potential switch be released when the elevator is in motion. The lower auxiliary contacts A_l are used to short-circuit the resistance in series with the closing coil L. The purpose of this connection is to insure a strong pull when closing the switch from the off position. After the switch pulls in, these contacts open and cut resistance in series with the magnet coil and reduce the current.

An overload magnet, O_m is sometimes used, is connected in series with one feed wire and is utilized to actuate a contact in series with the potential switch should the current exceed a predetermined amount.

A small single-pole double-throw knife switch S_p is shown on the left of the potential switch. With the single-pole switch thrown to the down position, the potential switch will not close automatically when the line switch is closed and the controller made alive, but will remain closed after it has been closed by hand provided all emergency switches are closed. With the single-pole switch in the up position, as in the Fig. 163, the potential switch

will close automatically when power is on the board, provided all emergency switches are closed.

General practice provides for the potential switch to be self-closing. The circuit for closing coil L on the potential switch is from its top main contact marked + through the switch S_p and the small fuse to L terminal at the top of the board, then into the conduit C_w and through the L and $+L$ contacts on the car-governor switch. From the governor the circuit returns to the top of the board and goes into the C_v conduit and up through the counterweight-governor switch, when used, and one set of contacts on the limit switch at the top of the hatchway, then to $+L''$ on the bottom limit switch through the slack-cable switch, when used, on the compensating sheave, back to the $+P$ terminal on the controller, down through the ARP resistance and its short-circuiting contacts A_l, through coil L and the contacts on overload relay O_m to $-P$ at the top of the board. From the top of the board the circuit again goes to the top hatchway limit switch and through contacts $-P$ and $-L'$, then through contacts $-L'$ and $-L$ on the bottom hatchway limit switch to the $-L$ terminal on the safety switch in the car. From the Y terminal on the safety switch in the car the circuit goes to the switch mounted on the safety plank under the car and from here to the Y' terminal on the board, then through a fuse and to the G' and $-'$ contacts on the car-governor switch, and returns to the $-'$ terminal on the board and the $-$ top contact of the potential switch, thus completing the circuit. This will cause the potential switch to close and complete the power circuit to the controller. A simplified diagram of the potential switch circuit is shown in Fig. 164.

The operation of the control will be considered under the following conditions: Throwing the car switch completely over to full-speed position up and stopping automatically at the top terminal landing. Any other conditions of operation will merely change the time rate of acceleration and stopping, with the exception of the brake operation, which will be explained for the condition of lifting full load to the top terminal landing.

Direction-switch Coil Circuit.—With the car-switch handle moved to full-speed up position, the circuit is completed for the up-direction switch B on the board, and it closes. This circuit is from the M_a contact on the + side of the potential switch through the heavy line to tap X on the left-hand side of the board. From tap X the circuit is through the fuse, $AR4$ resistance to terminal

SL' and through the shaft-door contacts, back to SL terminal on the board, then to between No. 5 contacts on the stopping switch mounted on top of the car. From $+U$ on the stopping switch the circuit returns to $+U$ on the controller, through closing coil B on the up-direction switch, N_r contacts on the non-reversing magnet G, to U' terminal at the top of the board. The circuit now goes to U' on No. 6 contacts of the stopping switch and to U and C on the car switch, then to C and $O-$ on the safety switch back to $O-$ on the board, down through a fuse and the right-hand auxiliary contacts A_c on the potential switch to the $-$ side of the line, thus causing the up-direction switch to close.

The up-direction switch pulling in, closes the contacts shown open and opens those shown closed in Fig. 163. The up- and

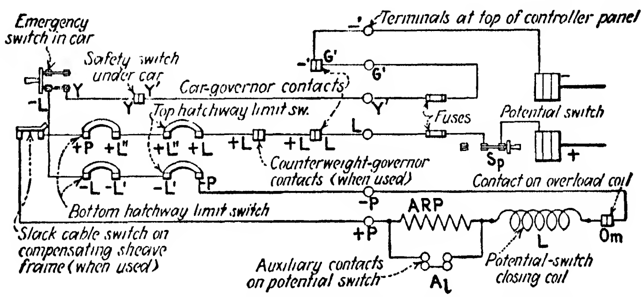


FIG. 164.—Simplified diagram of potential-switch circuit.

down-direction switches are mechanically interlocked so that the action of one direction switch when pulling in, causes the other switch to drop back to the extreme position open, so that the bottom contacts will close. These switches are so interlocked to prevent the bottom contacts on both switches closing at the same time, for should this happen, the armature would be short-circuited through these, causing a very severe stop. Closing the up-direction switch completes the circuit to the motor's armature, from the M_a terminal on the $+$ side of the potential switch through 2 and 4, and 1 and 3 contacts in parallel on the up-direction switch, to the left and down through the right-hand bottom contact of down-direction switch, which is closed when the up-direction switch closes. Then the circuit is through hold-down coil of down-direction switch to I through the armature and back to E on the board, through the minimum starting resistance and line marked 2 and 3, back through the left-hand bottom con-

tact on down switch to SB terminal, through the series winding of the brake back to SB' through the closed contact of auxiliary brake magnet O, to R on the maximum starting resistance to 9, through right-hand M_a contact of the potential switch, through the overload magnet to the negative side of the line.

Releasing the Brake.—The auxiliary making contacts, R_a, on the up-direction switch B, when closed, complete the circuit to the shunt winding of the brake from the + side of the line through the main contact on potential switch L through the left-hand auxiliary contact A_c through the up-direction switch auxiliary contacts R_a, BR resistance and to $+B$ terminal, then through the shunt coil of the brake magnet back through $-B$ line and small fuse, through the other auxiliary contact A_c on the potential switch to the − side of the line. The brake magnet then releases the brake shoes from the pulley and allows the motor to start on slow speed.

The initial lift of the brake is obtained by the combined action of the shunt and series winding. The action of the brake lifting closes the contact B_c mounted upon it, which provides a circuit through the auxiliary brake magnet O on the controller, from the bottom contacts R_a on the up-direction switch, through the ABM resistance, coil O and to the $-B'$ terminal and to the B_c contacts on the brake back to the $-B$ terminal on the board and to the − side of the line. The auxiliary brake magnet O closes, which first short-circuits the series winding of the brake and then open-circuits the line leading to this winding. This eliminates any sneak current through the series winding due to poor short-circuiting contact. A sneak current through the series winding of the brake would change the character of its action and should be avoided.

It has been shown that the armature is in series with the minimum and maximum starting resistance and the series winding of the brake at starting, the series winding of the brake being short-circuited by the O magnet after the brake has lifted. In addition to this circuit there is a bypass circuit across the armature to obtain a positive slow speed which could not be obtained otherwise, as load conditions would greatly vary the low speed with the starting resistance in series with the armature.

Resistance Connected in Parallel with the Armature to Obtain Slow Speed.—This bypass circuit is from a tap I' just below and between the direction magnets then to the I terminal on the

bypass resistance, through this resistance to 4′, through the bottom contact of the fast-speed magnet 4′ (*C*), through the blowout coils of fast-speed magnets *C*, *D*, *E* and *F* to *E* lead of the armature. From here the circuit is completed to the − side of the line as explained for the armature.

The fast- and slow-speed magnet *K* operates immediately upon either direction switch pulling in. It is connected in series with resistance, which is mentioned here particularly because the resistance is utilized for other means than for reducing current value (see Fig. 165). The contact which *K* operates short-circuits the shunt-field resistance of the motor. The final point in the car-switch completes a short-circuit across this magnet, causing it to release, cutting in the shunt-field resistance and getting final high speed of the motor. This cannot be done, however, until after the accelerating magnet *M* contacts pull in and the

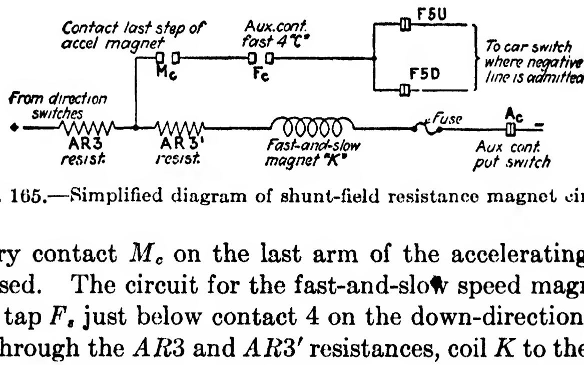


FIG. 165.—Simplified diagram of shunt-field resistance magnet circuit.

auxiliary contact M_c on the last arm of the accelerating switch has closed. The circuit for the fast-and-slow speed magnet *K* is from a tap F_s just below contact 4 on the down-direction switch, down through the *AR*3 and *AR*3′ resistances, coil *K* to the − side of the potential switch. The closing magnet *K* short-circuits the *SFR* resistance in the shunt-field circuit, providing full field on the motor during the period of starting. The conditions so far described are those that would obtain if the car switch closed contacts *U* and *C*, which would give the slowest operating speed. With the car switch in the full on position a number of other operations take place to bring the motor up to full speed. The second, third, fourth and fifth operations in accelerating the motor are the closing of the fast-speed magnet switches *C*, *D*, *E* and *F*.

Operation of Fast-speed Switches.—The first fast-speed switch to close is *F*, and the circuit for its coil is from the auxiliary contact R_a on the up-direction switch, through coil *F* and *AR*13 resistance to terminal *F*1 at the top of the board, and to between

No. 4 contacts on the stopping switch, to $F1U$ contact and to $F1U$ on the car switch and to the negative side of the line, as previously explained.

Fast-speed switch F, upon closing, cuts in the portion of the bypass resistance between 1′ and 2′ by opening its lower contact. The top main contact, closing, short-circuits the portion of minimum starting resistance between E and 1. The auxiliary contact F_f completes the circuit for fast-speed magnet E.

It should be noted that lower contacts 1′, 2′ and 3′ on the fast-speed magnets connect to 1′, 2′ and 3′ respectively on the bypass resistance, also top contacts 1, 2 and 3 connect to terminals 1, 2 and 3 respectively on the minimum starting resistance, although the connections are not shown.

A circuit to close the second fast-speed magnet switch E is obtained from the + line as for F, through coil E, resistance $AR14$, auxiliary contact F_f on F, to the $F2$ terminal on the board. From here the circuit is to between No. 3 contacts on the stopping switch to contact $F2U$ on the car switch and returns to the negative side of the line as previously explained. Energizing coil E causes contacts 2 to close and 2′ to open. Closing contacts 2 short-circuits the remainder of the minimum starting resistance, and opening contacts 2′ cuts in the portion of the bypass resistance between 2′ and 3′, thus increasing the speed of the motor. Closing auxiliary contacts F_e completes the circuit for fast-speed magnet coil D, which is the fourth step in accelerating the motor. A circuit is obtained for coil D from the same line as E, through D, resistance $AR15$, auxiliary contacts F_e to $F3$ terminal on the board and then directly to the F_3 contact on the car switch and to the negative side of the line.

It will be noticed that the circuit for D magnet coil does not pass through the stopping switch, but goes directly to the car switch. As this circuit is utilized when the motor is under load at the terminal landings, it will be further considered when the stopping at the terminal is discussed. The top main contact of D switch short-circuits the minimum starting resistance in the same manner as E switch; in fact, the contacts are paralleled. The bottom main contact inserts bypass resistance between 3′ and 4′, and auxiliary contact F_d completes the circuit to fast-speed magnet C.

Closing magnet coil C is the fifth step in starting the motor. A circuit for this magnet coil is from the same + line as for D, through coil C, resistance $AR16$, to terminal $F4$ and to between

the No. 2 contacts on the stopping switch, then to $F4U$ on the car switch and returns to the negative side of the line. Closing switch C opens contacts $4'$, which open-circuits the bypass resistance. Closing contacts 4 closes the circuit to the accelerating magnet M at the bottom of the board and closing auxiliary contacts F_c provides a circuit to be completed for the final speed only after the accelerating magnet M has closed all its contacts. The operation of the accelerating magnet which then follows is entirely automatic upon the closing of C magnet.

Accelerating-magnet-coil Circuit.—One side of the accelerating magnet is connected to the top main contacts of the direction switches at F_s where it obtains positive line, and the circuit continues through the accelerating magnet coil M through $AR2$ resistance, then through top contact 4 of fast-speed magnet switch C to point O in the starting resistance, the latter being connected to the negative line of the main circuit and to the armature, so that the circuit is completed from O to 9 and to the $-$ side of the line. This connection provides for any degree of acceleration desired between the minimum and maximum time required for the accelerating magnet to close its five contacts 5, 6, 7, 8 and 9. By shifting O closer to R the accelerating magnet connection is brought closer to the armature; that is, the voltage across coil M is more dependable upon the speed at which the armature rotates. The speed of the armature is approximately a measure of the voltage drop across its terminals, and when the accelerating magnet is connected across the armature terminals, the strength of magnet M will increase as the speed of the motor. Shifting connection O towards 9 increases the voltage drop across M, making it more independent of the speed of the armature until when O is connected at point 9, full line voltage is obtained across the accelerating magnet circuit, when magnet M will pull in its contacts rapidly and entirely independent of the motor acceleration.

The accelerating magnet M, upon operating, closes its five contacts in sequence, each short-circuiting a portion of the maximum starting resistance. It is to be noted that contacts 5, 6, 7, 8 and 9 on M connect two points, 5, 6, 7, 8 and 9 respectively on the maximum starting resistance. Contact No. 5 is the first to close and No. 9 the last.

Connecting Resistance in the Field Circuit.—The last contact arm of the accelerating switch closes an auxiliary contact M_c in addition to the one which short-circuits the last portion of

starting resistance, and this auxiliary contact provides for releasing the fast- and slow-speed magnet *K*. It was shown that *K* magnet obtained positive line from contacts on the direction switch, through *AR*3 and *AR*3′ resistances through *K* coil, small fuse, auxiliary contact on potential switch and to negative line. To release this magnet, negative line passes from *C* to *F*5*U* contact finger in the car switch, to *F*5*U* lead on No. 1 contact in the stopping switch to *F*5 on the controller, through auxiliary contact F_c on fast-speed magnet *C*, auxiliary contact M_c on the last arm of *M*, to a point between *AR*3 and *AR*3′ resistance in the *K* magnet circuit. Under this condition the negative side of the line is connected to both sides of *K* coil and is equivalent to short-circuiting this coil and causes it to release its contactor (see Fig. 165). The contacts on *K* magnet open the short-circuit across the *SFR* (shunt-field resistance), Fig. 163, which weakens the field and obtains the last and final speed of the motor.

The elevator is then running at full speed, and should there be a tendency to overspeed because of light load up or full-load down, the governor closes contact *G*, which short-circuits a portion of the *SFR* resistance, between − and *G*, to maintain a speed within definite limits. If this does not maintain the speed within a predetermined limit, contacts *G*″ on the governor switch close and short-circuit another section of the *SFR* resistance between *G* and *G*″. Attention is called again to the fact that the wiring diagram shows the position of the switches from the rear of the control panel, therefore switches are shown reversed to what these would appear facing the panel.

Stopping at the Terminal Landing.—Upon approaching the terminal landing, the contacts in the stopping switch, Fig. 163, open in the following order:

No. 1 opens and causes *K* switch to close by removing the short-circuit from across its coil, and again short-circuits the *SFR* field resistance, increasing the field strength and slowing down the motor.

No. 2 opens and causes fast-speed switch *C* to release and open its top main contact, thus opening the circuit to the accelerating magnet, which, releasing, cuts the maximum starting resistance in series with the armature. The bottom main contacts of *C*, closing, connect the bypass resistance across the armature.

No. 3 opens and causes fast-speed switch *E* to release, which closes its bottom contacts and short-circuits a portion of the

bypass resistance 2′ and 4′. The top main contacts open, but do not remove the short-circuit on a portion of the minimum starting resistance, since these contacts are in parallel with the top main contacts on switch *D*. Opening of the auxiliary contacts on switch *E* releases switch *D*. When the fast-speed switch *D* releases, opening its top main contacts removes the short-circuit from the section of minimum starting resistance between 1, 2 and 3. Closing the bottom contacts of *D* does not have any effect since the section of bypass resistance between 2′ and 4′ has already been short-circuited by switch *E* closing contacts 2′, therefore the only effective operation has been to open the short-circuit across the terminals of the minimum starting resistance.

No. 4 on the stopping switch opens the circuit through fast-speed switch *F*, which releases and opens its top contacts and removes the short-circuit across the section of minimum starting resistance from *E* to 1. The bottom main contact short-circuited the portion of bypass resistance between 1′ and *E*′. The elevator will now run at its minimum speed with all starting resistance in series with the armature and the minimum amount of bypass resistance across the armature terminals.

Should the load be heavy, the motor might be unable to raise it to the top landing with all resistance in series and the minimum amount of bypass across the armature. Should such be the case the auxiliary load magnet *H*, which is connected across the armature leads from *H*′ on the *I* lead through coil *H* and the *AR*6 resistance to *E*″ on the *E* lead, is so adjusted that if the armature slows down greatly, *H* magnet releases. The reason for this was outlined where it was explained that the voltage across the armature terminals was approximately a measure of its speed. *H* magnet, releasing, closes its contacts, which permits *F* magnet to close again and short-circuit a portion of the minimum starting resistance and cuts in that part of the bypass resistance between 1′ and 2′, increasing the voltage drop across the armature and giving a greater torque for the motor to raise the full load to the top-floor landing. It might be said that this should be unnecessary, as the resistance could be adjusted to eliminate this operation, which is so, but for true refinement of control and uniformity of slow-down at terminal landings with and without load this method is used.

The circuit for fast-speed magnet coil *F* is from the + side of the potential switch through coil *F* and *AR*13 resistance as before,

but instead of the circuit going to F_1 it is now through the contacts on H and back to $F3$ terminal at the top of the board and to the $F3$ contact on the car switch to C contact and returns to the $-$ side of the line.

Nos. 5, 6 and 7 contacts on the stopping switch open simultaneously. Nos. 5 and 6 each open one side of direction-switch magnet. No. 7 contact opens the parallel or discharge resistance PBR across the brake magnet. This provides for a quick positive stop at the terminals. The direction switch, releasing, disconnects the armature and brake from the line, at the same time releasing K magnet, which opens its contacts and inserts the SFR resistance in the shunt field.

Preventing Overtravel at the Terminal Landings.—Should the car overtravel the terminal landings, then either the top or bottom shaft-limit switches will be opened by the car, which will release the potential switch. When the top contacts of this switch open, power is cut off from the controller, and the auxiliary contacts A_c opening, open the brake and operating circuits. The bottom contacts of the potential switch, closing, connect the section of the bypass resistance between E' and I across the armature, and would result in a strong dynamic braking action to stop the elevator as long as the armature was in motion.

The down non-reversing magnet on switch G is so connected that only when the down-direction switch A is closed, coil G is connected across the armature. The contact opens the circuit to the up-direction switch and prevents reverse travel until the armature has practically come to rest.

The up non-reversing magnet I is connected so that only when the up-direction switch B is closed, coil I is connected across the armature. The function of this magnet is similar to G, but used for the opposite direction of travel.

There are two parallel circuits across the shunt winding of the brakes. One of these circuits PBR is of high resistance, the other is of low-resistance $PBR1$. At the terminal landings these parallel circuits are disconnected by means of the stopping switch on the top of the car. This circuit is opened by contact No. 7 in the stopping switch, one contact provided for each direction of travel. A simplified diagram of the brake circuits is shown in Fig. 166. The high resistance circuit PBR can be disconnected only during regular operation by the stopping switch. The low-resistance circuit $PBR1$ is taken through the auxiliary contacts

A_b on the direction switches and contact Q on the auxiliary brake-resistance magnet P. Since the auxiliary brake-resistance magnet is connected across the armature, contact Q is closed only when traveling at high speeds; then when the car-switch handle is centered, the auxiliary contacts A_b on the direction switches will close before the elevator comes to rest. This permits the brake magnet to discharge through both parallel circuits, when stopping from high speed.

When stopping from low speed, such as inching or a short run, the auxiliary brake-resistance magnet will not close its contact. Therefore, the brake magnet can discharge through the high resistance *PBR* only, thus insuring quick brake application.

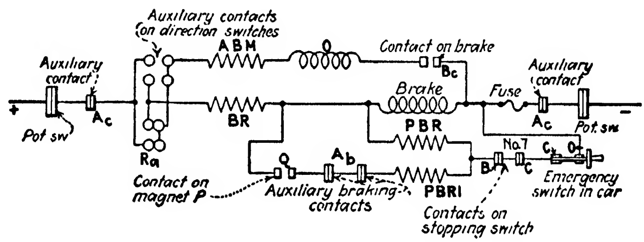


FIG. 166.—Simplified diagram of brake circuit.

Governor Prevents Overspeed.—The governor is equipped with two making and two breaking contacts and in this particular case will have four settings, all of which will be overspeed travel. The first setting closes a contact G which short-circuits a portion of shunt-field resistance between − and G, which should check the speed of travel. Should this not be effective, the second making contact G'' short-circuits an additional portion of shunt-field resistance, giving a further check to the speed of travel. Such conditions as overload, falling elevator, open shunt field, poor connections at definite places would prevent the governor making contacts G and G'' from producing the desired results, in which case the third setting, contacts G' and L, provide for the opening of the potential switch magnet. When the potential switch releases, it provides a hard dynamic stop for the elevator motor, disconnecting the line from the equipment and opening the brake circuit. The fourth setting of the governor provides for applying the car safeties. This action is rarely obtained, as the condition which should call for it is only when the elevator car is mechani-

cally disconnected from the elevator machine, which will be only when the hoisting ropes have broken.

It must be remembered that the controller described in the foregoing is one for a definite purpose and that this description appertains to this control only. The reader by a little study can understand any control of a similar nature, as the general principles are similar.

CHAPTER XI

FULL-MAGNET SINGLE-SPEED ALTERNATING-CURRENT CONTROLLERS

Limit of Car Speed for Single-speed Control.—Elevators with hand-rope control are rapidly being superseded by those having a full-magnet type—that is, car-switch or push-button control—or a combination of the two—dual control. Safety codes, local regulations and insurance rates have had much to do with this transition. Where hand-rope control is limited to car speeds of

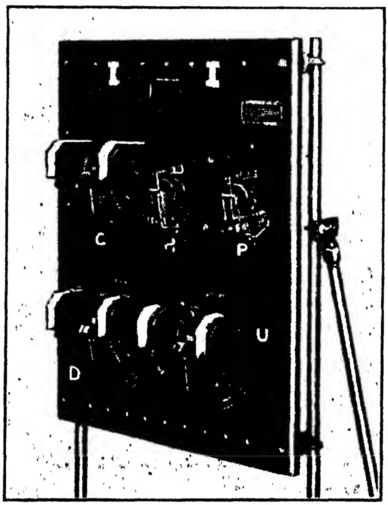


FIG. 167.—Controller for connecting a squirrel-cage motor directly to the line. U and D, direction contactors; C, line contactor; P and P_1, reverse- and open-phase relays.

about 100 ft. per min. or less, full-magnet control is applicable to any car speed. With single-speed control 200 ft. per min. is about the limit of car speed, on account of the difficulty in making good landings. Although in some cases single-speed control has been used for considerably higher speeds, good practice would dictate 200 ft. per min. or less. For medium-speed elevators multi-speed motors are required in alternating-current elevator

service, to provide the necessary slow down. With single-speed motors of either the squirrel-cage or the slip-ring type no slow-down action or dynamic braking effect can be obtained and the car must be stopped from full speed with the mechanical brake. This, therefore, limits single-speed motors to slow-speed service.

A single-speed high-torque squirrel-cage motor with full-magnet control is limited in application to car speeds at which smooth acceleration and stopping can be obtained. Up to 100 ft. per min. smooth acceleration can generally be obtained when the motor is connected directly across the line and good stopping can be obtained with the ordinary type of brake. At higher car speeds one or more steps of starting resistance are necessary for smooth starting and acceleration, while smooth stopping depends upon the brake pressure being gradually applied. This brake action is most commonly obtained by the use of a dashpot to retard the brake's application.

Open-phase and Reverse-phase Relays.—In Fig. 167 is shown a Westinghouse controller for starting a squirrel-cage motor by connecting it directly to the line, and Fig. 168 is the wiring diagram for this controller when applied to a traction-type elevator. The relays P and P_1 give phase-failure and reverse-phase protection to the motor.

On relay P_1 the coil is connected directly across the line from L_3 on potential switch C to L_1 on the up-direction switch U. Energizing this coil causes the contact of relay P_1 to close and complete a circuit for coil P, from L_3 through inductance X, contact P_1 and coil P to L_2 line. Making this circuit alive causes the contact of relay P to close. A second circuit is formed through inductance X which includes resistances R and R_1 to the L_1 side of the line. The combined effect of the two circuits through inductance X is to cause relay P to open in case of a reverse phase.

If either line L_3 or L_1 opens, relay P_1 will open and interrupt the circuit to coil P and this relay will also open, so that the controller cannot be operated from the car switch. An open in line L_2 will cause relay P to open, and as the contact of this relay is in the car switch circuit, the controller cannot function with this contact open.

Controller for Connecting the Motor Directly to the Line.—Assume that the relay contacts P and P_1 are closed, then there is a circuit completed to the car switch from L_1, through contact P, fuse F, the door contacts and returns to O on the controller and

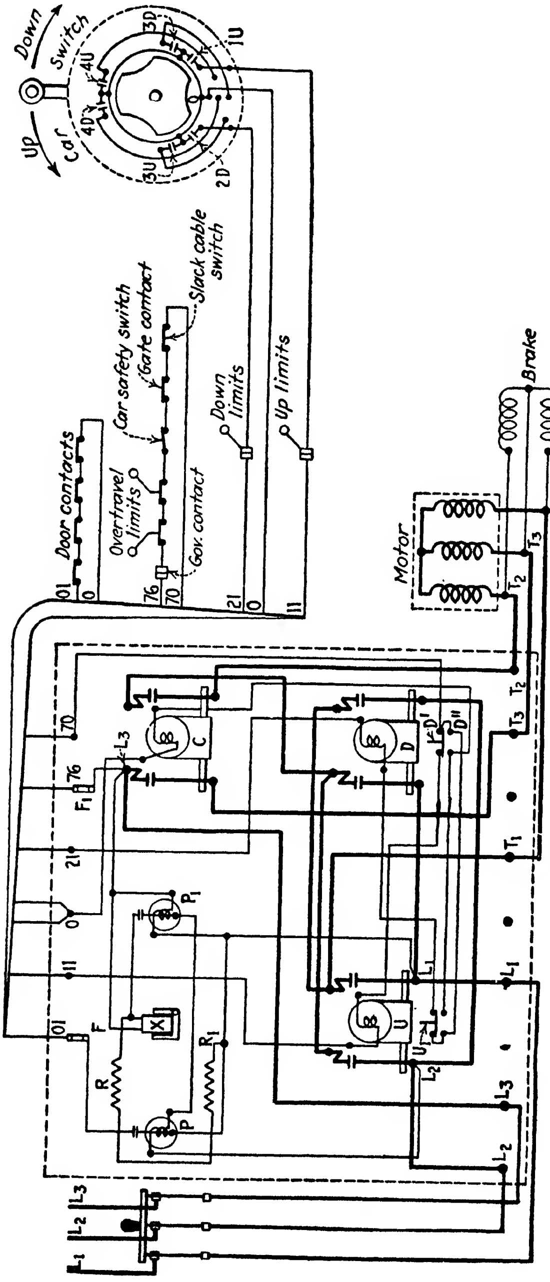


FIG. 168.—Wiring diagram for single-speed squirrel-cage motor controller with electrical interlocks on direction switches.

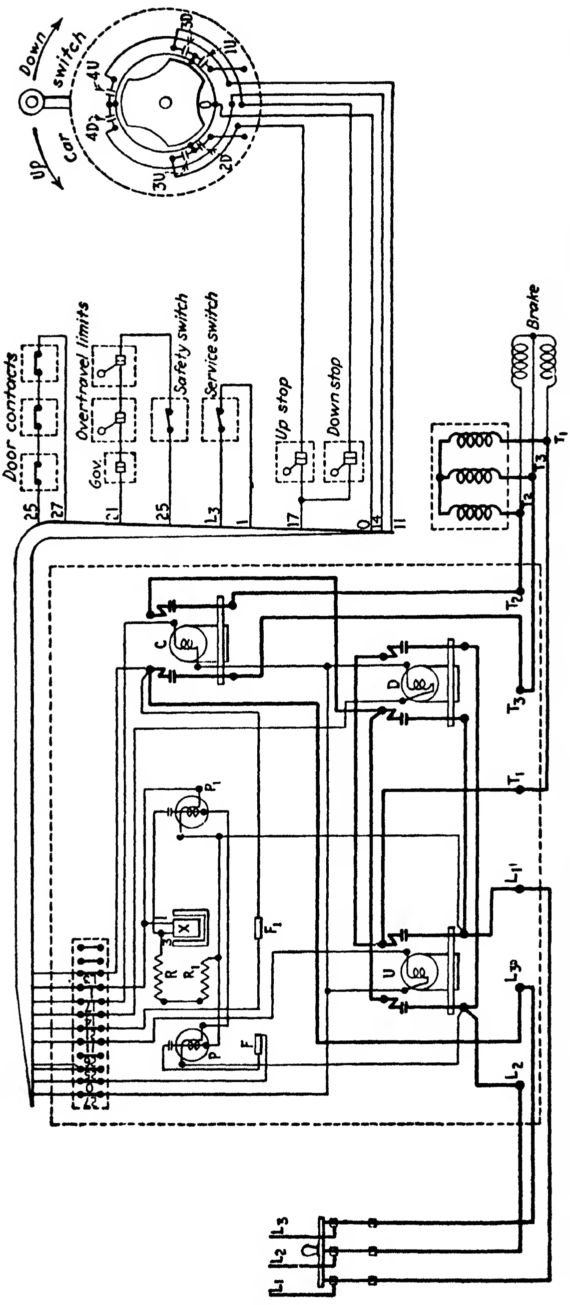


FIG. 169.—Wiring diagram for single-speed squirrel-cage motor controller with the line and direction switches controlled through the car switch.

to the common connection on the car switch. With the car switch thrown to the down position, contacts $2D$, $3D$ and $4D$ close and a circuit is completed through $2D$, the down limit switch to 21 on the controller. The circuit then continues through the coil of down-direction switch D, auxiliary contacts U_1 on up-direction switch U, through the slack-cable switch, the gate contact, car-safety switch, over-travel limits, governor switch and returns to the controller, then through fuse F_1 and to the L_3 line. Completing this circuit causes coil D to close its contactor.

When closing, contactor D opens its auxiliary contacts D' and closes D''. The closing of auxiliary contacts D'' completes the circuits for the coil of potential switch C, from O terminal at the top of the panel, through coil C, auxiliary contact D'' to terminal 70 and to L_3 line as previously explained. Completing this circuit causes contactor C to close and with direction switch D completes the circuits to the motor.

At one instant, the motor circuits will be from L_3 line, through the left-hand contact of potential switch C to T_3 on the motor. After including the motor windings, the circuits return to T_1 and T_2 on the controller, then from T_1 through the right-hand side of the direction switch D to line L_2. From terminal T_2 the circuit is through the right-hand side of potential switch C and the left-hand side of direction switch D to line L_1. This connects the motor directly to the line. The brake coils are connected to the motor terminals, therefore are energized with the motor and release the brake and the motor starts and comes up to speed.

For up direction, the circuits are the same as already explained, except that coil U is energized instead of D, and when contactor U closes, it reverses leads T_1 and T_2 to the motor and causes it to run in a reverse direction.

On the car switch with the hookup, Fig. 168, only two of the six contacts are used, the other contacts being used for other arrangement of connections. Figure 169 shows the connections for controlling the potential switch through contacts on the car switch instead of auxiliary contacts on the direction switches D and U, as in Fig. 168. The phase-relay connections are the same in both diagrams, except that in Fig. 169 a service switch is connected in series with the coil of relay P_1. The circuit for coil P_1 is from L_1 line through the coil to terminal 1 at the top of the panel, then through the service switch and back to line L_3 on the controller. This switch may be located in the car and provides a means of

disconnecting the phase relays from the line when the elevator is not in service and saves the power that would otherwise be expended in these coils.

When the car switch is closed to either the down or up position, a circuit is made for one of the direction switch coils *D* or *U* and another for the potential switch *C*. Assume that the car switch is in the down position, then a circuit is completed from line L_1 through the contact of relay *P*, fuse *F* to the common connection *O* on the car switch. Contacts 3*D* and 4*D* will be closed with this switch in the down position. Then, from *O* on the car switch, one circuit is through contact 3*D*, the down limit switch to 17 on the controller and through the coil of potential switch *C*, through the door contacts and return to terminal 25 on the control panel, then through the safety, overtravel-limit and governor switches to 21 terminal on the controller and to L_3 line.

From 4*D* on the car switch, a circuit is made to terminal 14 on the controllers through the coil of direction switch *D* and then through the limit switches to line L_3 as explained for potential-switch coil *C*. Making these circuits alive causes switches *C* and *D* to close and apply power to the motor and brake, as explained for Fig. 168.

Use of Sequence Relays.—It is not an uncommon practice of elevator operators, when door contacts are used, to pull the car switch to the on position and then close the landing door to start the car. This puts a service on these contacts that they are not designed for and is a source of trouble as well as a certain element of danger. This practice can be prevented by using sequence relays. With these relays, if the car switch is moved to either on position before the landing door is closed, the control magnets cannot be energized until the car switch is moved to the off position, the door closed and then the car switch moved to the on position.

Controller Using One Step of Starting Resistance.—To provide smooth starting of the elevator and to keep down the inrush current at starting, one section of resistance may be connected in series with the stator winding of the motor, on slow-speed elevators. On high-speed elevators the starting resistance is generally cut out in several steps. Figure 170 is the front view of a Cutler-Hammer controller for starting a squirrel-cage motor through one step of resistance, and Fig. 171 is a wiring diagram of this type of controller for a traction machine. The car switch on the

wiring diagram has three points for each direction. On some controllers this would indicate that the controller was arranged for two speeds. However, in this case there is only one speed, one point on the car switch in each position being from the direction switch and the other for the potential switch.

On the phase-reversal relay P the two coils are connected directly to the three lines L_1, L_2 and L_3. As long as the power conditions are correct, the contact on this relay will remain closed and completes the circuit for the potential-switch coil M. Assume

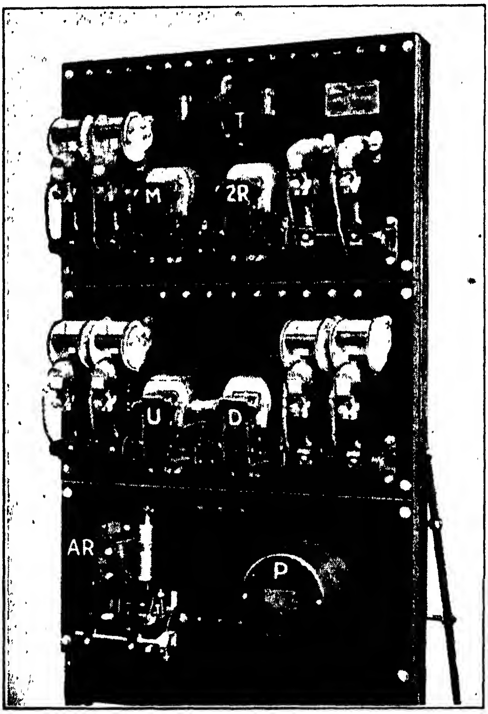


FIG. 170.—Controller for starting squirrel-cage motor through one step of resistance.

U and D, direction contactors; M, line contactor; $2R$, accelerating contactor; AR, timing relay for accelerating contactor; P, reverse- and open-phase relay; and T, test switch for operating the car at the controller.

that the car switch is moved to the down position. In this position contacts N, 3 and 1 will be connected together. Closing of the car-switch contacts completes a circuit for the potential-switch coil from the L_3 line up to N_2 at the top of the controller, then through the up-overtravel hoistway limit switch, to N_1 on

the down-overtravel hoistway limit switch and to the junction box in the hoistway. In the hoistway terminal box, line N branches, one branch going to the center of the test switch on the controller and the other to the center of the car switch. So far, the control circuit is common to both the potential switch and the up- and down-direction switches.

Starting at the car switch, with it held in the down position, a circuit is provided from 3 on this switch through the down terminal limit switch to 40 on the controller. From terminal 40 the circuit goes to the test switch and to auxiliary contact M' on potential switch M, through the coil of timing relay AR to termi-

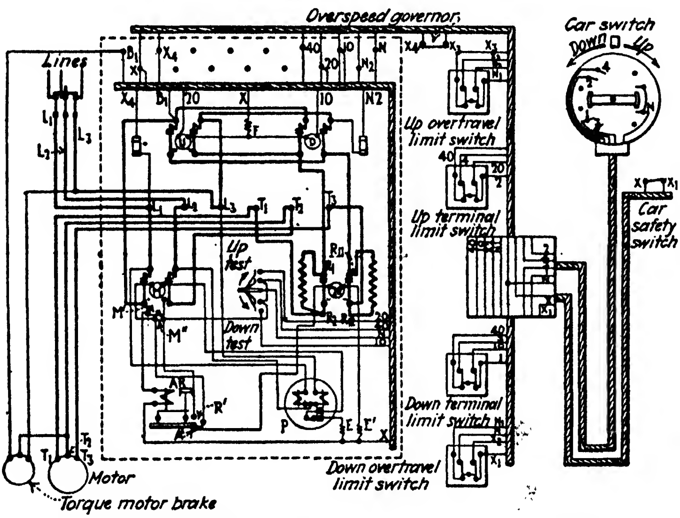


FIG. 171.—Wiring diagram of the controller Fig. 170.

nal X at the top of the panel. From X at the top of the panel, the circuit is through the safety switch in the car, overtravel limit switches, the governor switch, and returns to X_4 at the top of the controller and goes to the L_1 side of the line. Energizing this circuit causes the timing relay AR to pull up its core and, in doing so, opens contact A' and closes contact R'. This operation opens the circuit to coil $2R$ and prevents it from closing its contacts and short-circuiting the resistance in the stator circuit of the motor. Closing contact R' completes a circuit for coil M of the line contactor, from 40 through contact R', coil M, contacts of phase relay P, resistance E, to X and to the L_1 side of the line, as previously explained. Making coil M alive causes it to close its contactor.

From 1 on the car switch a circuit is completed for the down-direction switch through the down terminal limit switch, to 10 at the top of the control panel. One branch from 10 goes to 10 on the test switch, and the other through coil D and resistance F to X and to the L_1 side of the line, as previously traced through. With the circuit through coil D alive, its contacts are closed, and this operation in conjunction with contactor M closing completes the circuits to the motor. These circuits may be traced from line L_2 through the right-hand contact of switch M to T_2 on the motor, through the motor windings to T_1 and T_3 terminals on the controller. From T_1 the circuit continues through resistance R_2R_1, the left-hand side of direction switch D and of line switch M to the L_1 side of the line. From T_3 another circuit goes through resistance $R_{12}R_{11}$, the right-hand side of direction switch D to the L_3 side of the line.

Brake Torque Motor.—The three leads from the brake torque motor are energized with the closing of the potential switch. This releases the brake, and the motor starts with the resistance in series with the stator winding. Where a magnet is used to release the brake, its coil is connected directly to the motor terminals. Where a torque motor is used, as in the figure, it must be connected outside the direction switches or it would be reversed with the motor and would not release the brake in one direction.

When contactor M closed, it opened auxiliary contacts M' and closed M''. Opening contacts M' interrupts the circuit through the coil of timing relay AR, and this relay begins to open, but is retarded by a dashpot. Closing contacts M'' completes a circuit for coil M, without going through contact R' on the timing relay so that contactor M remains closed when contact R' opens. When the timing relay opens, it closes contact A' and completes a circuit through coil $2R$. This circuit is also through contacts M'' on contactor M, then through contact A' on the timing relay, coil $2R$, resistance E' to X, through the safety devices as previously explained to the L_1 line. Energizing coil $2R$ causes it to close its contacts and short-circuit resistances R_1R_2 and $R_{11}R_{12}$ out of the stator circuit and the motor comes up to full speed.

On up direction, the same series of events takes place, except direction switch U closes instead of D. The test switch on the controller allows operating the elevator from the control panel without going on the car, when locating trouble or when testing the equipment.

Stopping at the Terminal Landings.—With the car in the down motion, on approaching the bottom landing, the terminal limit switch is opened by the car. Opening of this switch performs the same functions as centering the car switch and the car should stop. If the car goes a short distance below the floor, it will open the overtravel limit switch, which will open the common circuit *N* to the car switch and the common return circuit from the controller contactor coils.

When the car runs on the overtravel limits, the machine cannot be started until the car has been raised enough for this switch to close. This generally can be done by releasing the brake and moving the car by hand. On the up motion this is not so easily done by hand, as the car has to be moved down and the counterweights raised. As the counterweights generally equal the weight of the car plus 40 per cent of the rated load, they are heavy to raise unless overbalanced by a load in the car. Contactor *M* and the proper direction switch can be held closed by hand and the car moved to the floor by the motor. When doing this, care must be exercised to close the direction switch that will cause the car to move in the right direction. This is particularly true of a drum-type machine, or the car or counterweights may be jammed into the overhead work and serious damage done to the equipment. If the car or counterweights land with a drum-type machine, the cables should be inspected to see that they are in the proper grooves on the drum and sheaves before attempting to move the car, and also see that the cables are not slack.

CHAPTER XII

SINGLE-SPEED CONTROLLERS FOR ALTERNATING-CURRENT SLIP-RING MOTORS[1]

Control for Drum-type Machine.—An elevator machine operated by a single-speed slip-ring type alternating-current motor, as in Fig. 172, compares favorably in compactness and

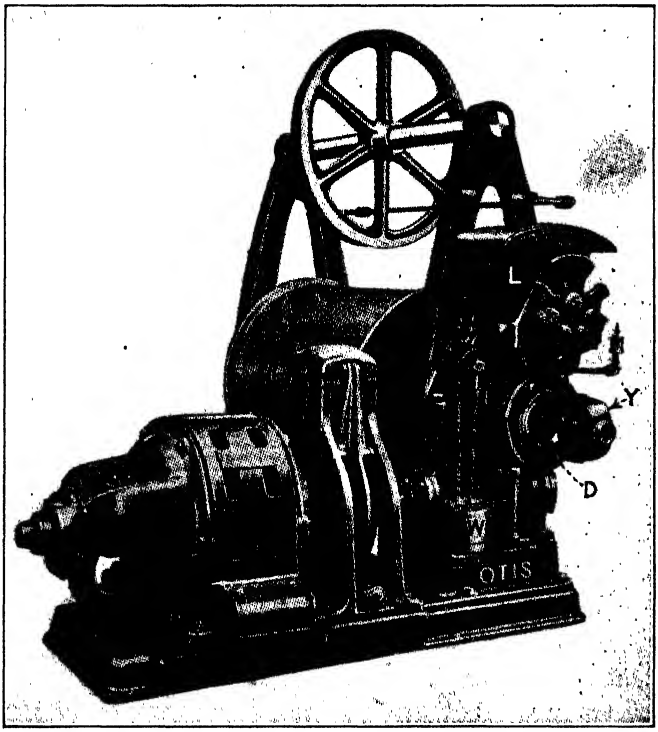


Fig. 172.—Alternating-current drum-type machine.

durability with the single-speed direct-current machine. The control of a single-speed elevator machine operated by a slip-ring

[1] William Zepernick, Otis Elevator Co., supplied a large part of the material in this chapter.

type alternating-current motor is simplicity itself; such a controller is shown in Fig. 173. On it *A* is the down-direction and *B* the up-direction switch, which controls the direction of the motor; *P* is the potential switch which opens and closes the main-line circuit and must be closed for either direction of the motor; *O* is the master accelerating switch and *N*, *M* and *L* are the auxiliary accelerating switches, all four of which close and cut out the resistance connected in the rotor circuit. The rotor resistance is made

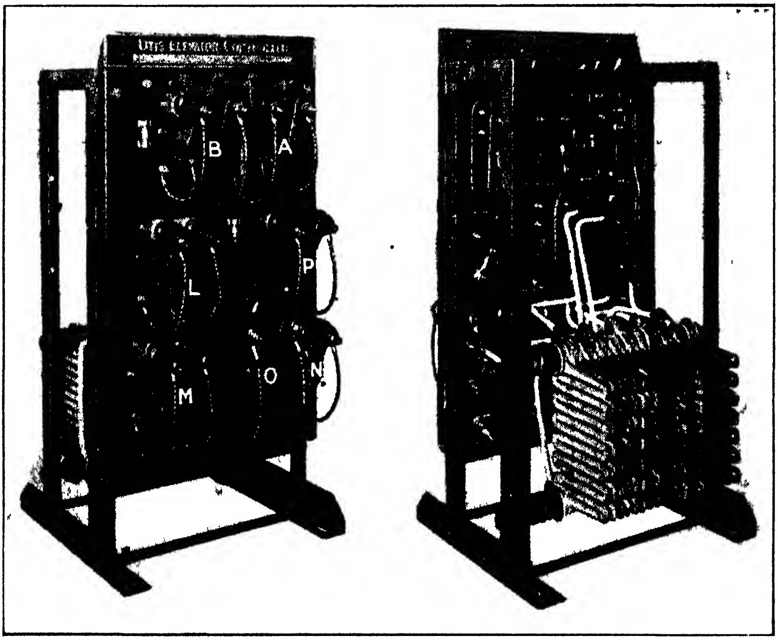


FIG. 173—Otis type No 1½ single-speed alternating-current elevator-motor controller

up of cast-iron grids and is shown in the rear view of controller on the rignt-hand side. This resistance is connected to the slip-rings and is gradually short-circuited out by accelerating switches already referred to in the foregoing.

Some objection might be raised to calling a slip-ring motor a single-speed machine, but for elevator service an alternating-current motor, if not running at high speed (all motor resistance cut out), will give very poor speed regulation; that is, when the car is going up with full load the speed would be slow, while going

down the speed would increase to such a point that the speed governor would probably set the safeties. In order to remove the possibility of an operator running the elevator on other than high speed, the car switch for this type of elevator controller is equipped to obtain but one running position for each direction. The circuit for the accelerating magnets is closed by the direction switches, and the time element required to short-circuit all rotor resistance is obtained by means of an air dashpot on the master accelerating magnet.

Functions of Car-switch Control.—The car-switch control, shown with the cover removed in Fig. 174, is provided with six

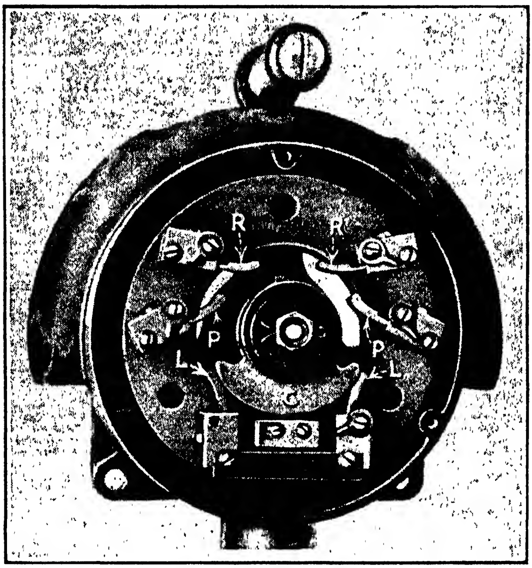


FIG. 174.—Elevator car switch.

contact fingers, three for each direction. The two lower contact fingers *L* are connected together and constitute the car-switch feed. Moving the switch handle in either direction permits one of these lower fingers to remain in contact with the contactor *C*, which engages the two fingers provided for each direction. Contact fingers *P* complete the circuit for the potential switch. This circuit is also controlled by protective devices, such as final limits, emergency switch, reverse-phase relay, etc., when provided. The top contact finger *R* provides the circuit to the direction- switch

magnet as determined by the position of the car-switch control handle. The brake and master accelerating magnets are connected across the motor feeders, and immediately upon the motor receiving power, the brake releases and the master accelerating switch is energized. Lifting the master accelerating switch, Fig. 175, is controlled by means of an air dashpot, which can be quickened or checked by means of an adjusting screw *S*. As the master accelerating switch pulls in, two small contact fingers,

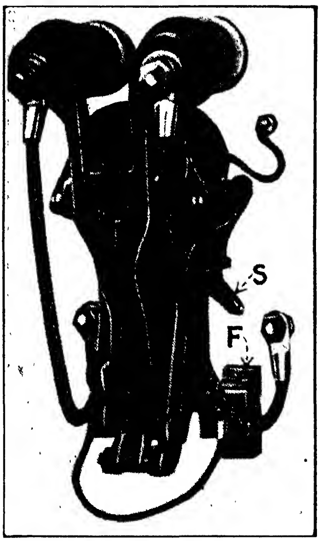


FIG. 175.

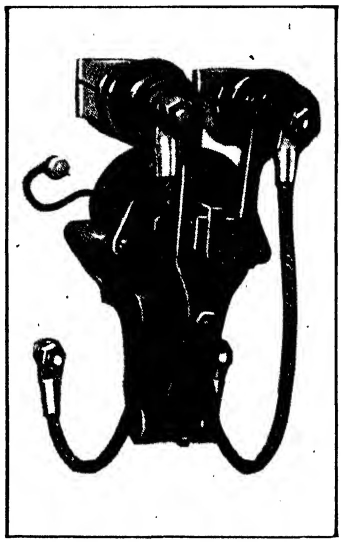


FIG. 176.

FIGS. 175 and 176.—Accelerating contactors on controller, Fig. 175.

FIG. 175.—Master accelerating magnet switch. FIG. 176.—Auxiliary accelerating magnet switch.

located at *F*, are caused to move over three contact segments, which in turn closes circuits for the three auxiliary accelerating switches, one of which is shown in Fig. 176. As these fingers pass beyond the contacts, the auxiliary accelerating switches are released and drop out. When the master accelerating switch has pulled in to the limit of its travel, the main contacts on *O*, Fig. 173, close and short-circuit all the rotor resistance. The small contact fingers at *F* (Fig. 175) have then traveled beyond the contact segments and the three auxiliary accelerating switches are released. These small contacts are arranged so that each

successive accelerating switch has pulled in before the preceding switch is released.

An arrangement that eliminates this method of control is the use of auxiliary contacts on each accelerating magnet that closes the circuit for the magnet that follows. The last step of the accelerating magnet closes a contact to become self-holding, and at the same time opens a contact which releases the preceding accelerating switches.

Reversing Switches.—The reversing switches, Fig. 177, are provided with an interlocking bar *C*, which prevents both switches from being either manually or electrically operated at

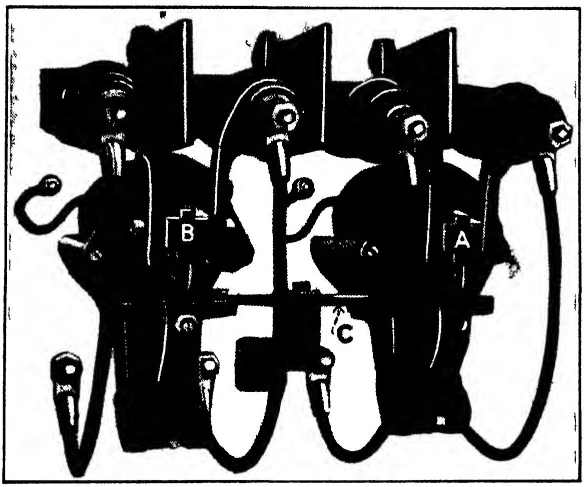


Fig. 177—Motor-reversing magnet switches.

the same time. If these switches should both close at the same time, a destructive short-circuit would result.

With the drum machine an automatic limit switch, shown at *L*, Fig. 172, is provided, which will stop the machine automatically at the terminal landings, and in addition open the main-line circuit to prevent the machine pulling the car or counterweight into the overhead work. Limit switches are placed in the hatchway, which are opened by a stationary cam attached to the car in case the latter goes a certain distance beyond the top and bottom landings. The opening of the shaft limit switches opens the potential switch on the controller, which interrupts the main power circuit Shaft-door contacts as well as gate contacts may

be used, so that the elevator cannot be started until the doors and gate are closed.

The complete wiring of the controller when used in connection with a drum-type machine is shown in Fig. 178. In order to

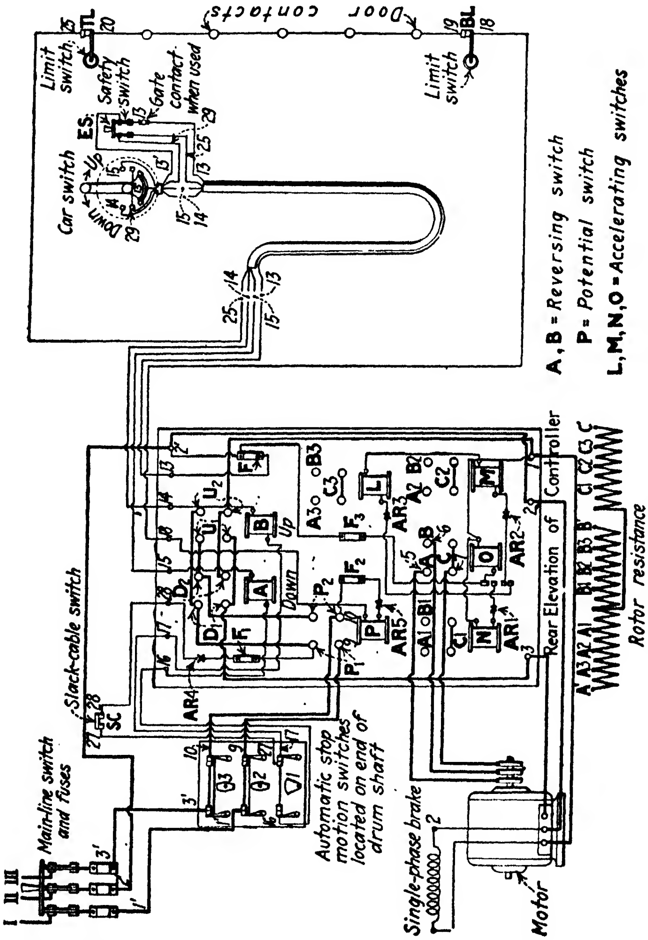


FIG. 178.—Wiring diagram of the controller, Fig. 173.

obtain a clear conception of the circuits, simplified drawings are shown in Figs. 179 and 180. Figure 179 shows the connections when the elevator is stationary and Fig. 180, when the elevator is ascending.

In Figs. 178 to 180, A is the down-direction magnet; D_1 and D_2 contacts closed by A: B, up-direction magnet; U_1 and U_2,

contacts closed by B; P, potential switch; P_1 and P_2, contacts closed by P; N is the first auxiliary accelerating magnet; M, second auxiliary accelerating magnet; L, third auxiliary accelerating magnet; O, master accelerating magnet; F to F_3, auxiliary fuses; BL, bottom-limit switch; TL, top-limit switch; DC, door contacts; ES, emergency switch in car; SC, slack-cable switch; O_1, O_2 and O_3, contacts controlled by master accelerating magnet; GC, gate contact when used in connection with collapsing gate on car. Nos. 1, 2 and 3 are automatic contacts operated by traveling nut on end of drumshaft at D, Fig. 172.

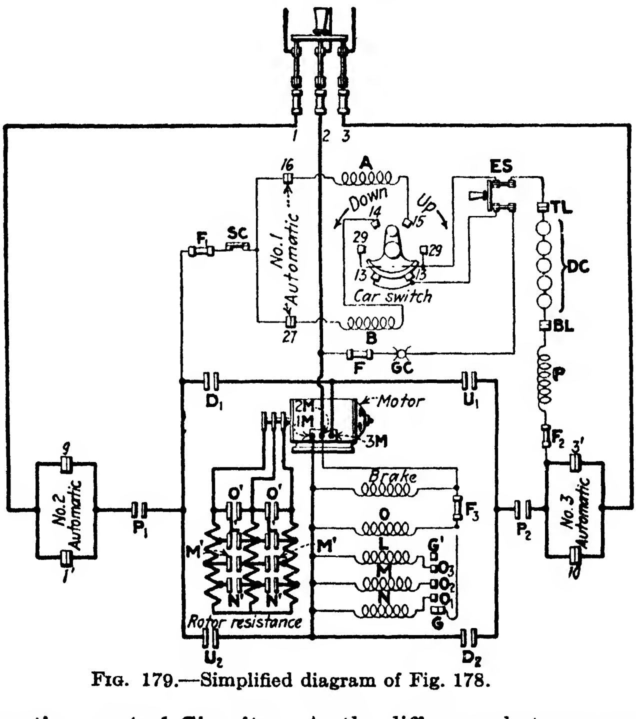


FIG. 179.—Simplified diagram of Fig. 178.

Direction-control Circuits.—As the difference between ascending and descending merely depends upon which direction magnet is energized, the operation of the controller and motor will be considered for the elevator ascending. Door and gate contacts have been indicated, although not always installed. The emergency switch in the car is of the double-pole single-throw type. One side of this switch, together with the gate contact, completes the car-switch feed line, and both must necessarily be

closed to operate the elevator. The door contacts, in series with the final-limit switches, *TL* and *BL*, and one side of emergency switch, complete the circuit from the car switch to the potential switch *P*. These door contacts must be closed in order for the elevator to operate.

When the car-switch control handle is moved in the up position to engage the center contact finger, as in Fig. 180, the circuit is complete from main line 2 through fuse *F*, gate contact *GC*, the

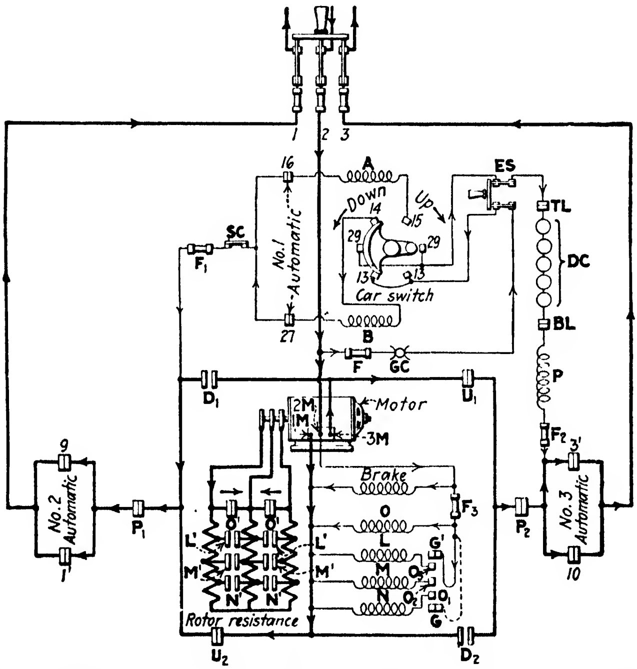


FIG. 180.—Same as Fig. 179, except contacts closed for up-motion.

lower side of the safety switch *ES* to 29, through the top side of the safety switch *ES*, top hatchway limit *TL*, door contacts *DC*, bottom hatchway limit *BL*, through coil *P* of the potential switch, contact 3′ on automatic No. 3 and back to No. 3 side of the line, as indicated by the arrowheads. Energizing coil *P* of the potential switch causes it to close contacts P_1 and P_2 as shown.

There is also a circuit from contact 13 on the car switch to contact 14 through coil *B* on the up-motion contactor, to contact 27

on No. 1 automatic, through the slack cable switch SC, fuse F_1, to contact P_1 on the potential switch, and through contacts 9 and 1′ on automatic No. 2 to the No. 1 side of the line. Energizing coil B on the up-motion reversing switch causes it to close contacts U_1 and U_2. When contact U_2 is closed, a circuit is made for the brake coil from line 2 to terminal $2M$ on the motor, then around through the brake coil to contact U_2, to P_1 and through automatic No. 2 to No. 1 side of the line. This causes the brake to be lifted, and the motor is ready to start.

The motor circuit is from line 2 to $2M$ terminal on the motor, through the motor windings to terminals $1M$ and $3M$. From terminal $3M$ the circuit is to contact U_1 on the reversing switch, to P_2 on the potential switch, through automatic No. 3 and back to No. 3 side of the line. The other circuit from the motor is from terminal $1M$ to contact U_2 on the reversing switch, through P_1 and automatic No. 2 to line No. 1, as indicated by the arrowheads. Energizing these circuits causes the motor to start with all the resistance in series with the rotor circuit.

Master Accelerating Magnet.—The master accelerating magnet O is also connected across one phase of the motor, and the circuit for its coil is from $2M$ terminal on the motor through fuse F_3 and coil O to contacts U_2 and P_1, automatic No. 2 and to No. 1 side of the line. This energizes coil O, and it starts to close the accelerating magnet, but is retarded from doing so by dashpot S, Fig. 251. As the switch closes, an auxiliary contact finger G is caused to move. When G rests on bottom contact O_1 a circuit is completed through coil N, which closes contacts N' and N' and short-circuits out the bottom sections of the rotor resistance and increases the speed of the motor. When G moves onto contact O_2, coil M is energized and closes contacts M' and M', cutting out another section of rotor resistance and further increasing the speed of the motor. Next coil L is energized and closes contacts L' and L', short-circuiting another section of rotor resistance. Contacts O' and O' are mounted on the accelerating contactor, and when this contactor has completed its travel contacts O' and O' are closed by it, thus short-circuiting all the rotor resistance out of circuit and the motor comes up to full speed. In this latter operation contact G moves onto G', thus opening the circuit through L and causing contactor L' to open, contacts N' and M' having opened previously to this. This permits only the master accelerating magnet to be energized when the motor is under way.

The contacts closed by the accelerating magnet short-circuit the rotor resistance in four steps. This resistance, shown in Fig. 173, on the rear of the controller is connected to the rotor winding by means of the brushes and slip rings shown in Fig. 180.

Top-and-bottom Limit Switches.—With the drum type of machine, upon approaching the terminal landings, should the elevator operator neglect to center the car-switch control handle, the automatic will first interrupt the current to up-direction magnet *B*, by opening contact 27 on automatic No. 1 and release direction magnet *B*. Releasing the direction-magnet circuits will open contacts U_1 and U_2, thus interrupting the current to the motor and bring the machine to rest.

Should the elevator slide an abnormal distance, however, the top limit *TL* will open, preventing the elevator from being operated in either direction, as this will open the circuit to the potential switch *P*. As the limit switches in the hatch are operated by means of cams attached to the elevator car, it is necessary to lower the car by manual operation of the potential switch *P* and the down-motion switch *A* or by means of a crank wrench upon the motor shaft.

Should the elevator travel beyond the final limit switch, automatic contacts Nos. 2 and 3 will be opened, interrupting the line circuit. In this case, to get the elevator into operation, it will be necessary to use a crank wrench or short-circuit the automatic contacts and manually operate the down-direction switch *A* and the potential switch *P*. If the car were in the down motion and ran by the bottom landing onto the bottom hatchway limit *BL*, to get the car up it would be necessary to operate by hand the up-motion contactor *B* and the potential contactor *P*, or by using a crank wrench on the motor shaft. Great care should be taken when doing this, for should the wrong direction magnet be closed serious damage may result. When using this method, a person should be stationed to note if the elevator is moved in the proper direction. The elevator should be moved the shortest distance possible until the proper direction is determined.

For those who wish to do so, the circuits on the simplified diagrams, Figs. 179 and 180, can be easily identified on Fig. 178 and can be traced out in the same way as explained in Fig. 180. The rotor resistance is not connected in Fig. 178, but its terminals are lettered as are those to which it connects on the accelerating contactors *L*, *M*, *N*, and *O*. The various contactors on Fig. 178 are

also indicated on Fig. 173. However, it will be noted that they are in reverse order on the diagram to what they are on the photograph; this is due to the Fig. 178 showing a rear view of the controller.

Automatics Nos. 1, 2 and 3 are operated by a traveling nut on a screw attached to the drum shaft, shown at *D*, Fig. 172. The nut is held stationary by means of a balance weight *W*, attached to a chain. The number of revolutions of the screw is determined by the revolution of the drum, which represents the travel of the elevator. At either terminal landing the traveling nut has a definite position on the screw. At these points stationary nuts are clamped to the screw and so constructed as to engage the traveling nut and turn the latter on the former. The traveling nut is equipped with wings which engage the yoke *Y*, causing it to turn at terminal landings. The yoke is geared to the stopping switch *L*, and by means of cams the automatic contacts are opened as described in the foregoing.

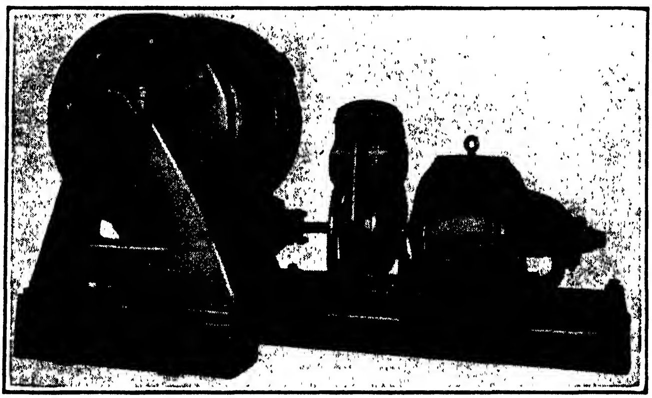


Fig. 181.—Single-wrap traction elevator machine.

Traction-type Machines.—Present-day practice tends toward the traction-type machine. The drum-type machine is necessarily cumbersome, particularly for higher rises, and is subject to the danger of serious accidents caused by the car or counterweight being drawn into the overhead works, due to improper setting of the limits or their failure to function. Such conditions are liable to cause the hoist or counterweight cable to part and may result in a serious accident. The traction-type machine is free from the danger of having the car or counterweights strike the overhead

works, since the driving power to the car or counterweights is obtained through traction of the ropes upon the driving sheave To obtain this traction, the hoisting ropes on each side of the driving sheave must be loaded. In the event that the counterweight or car lands on the bumpers provided in the pit, the load is relieved on one side of the driving sheave and the machine loses traction and prevents either the car or the counterweight from being pulled into the overhead work.

Automatic Limit Switches.—With the traction-driven elevator automatic limit switches cannot be used on the machine, since any

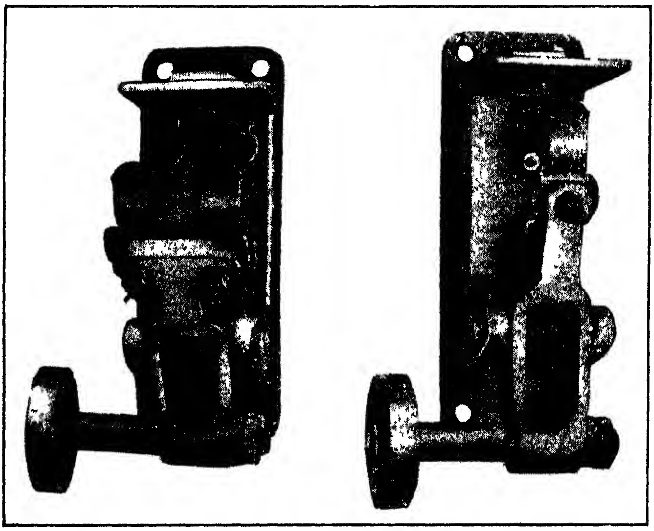


Fig 182. Fig 183.

Figs. 182 and 183.—Hatchway limit switches

shifting of the cables on the traction sheave will change the position of the car in the hoistway relative to the time of opening the machine limits. The machine automatics have been replaced by hoistway limit switches, either mounted on the car hitch beam and operated by fixed cams in the hatch or mounted in the hoistway and operated by a cam mounted on the elevator car. This arrangement provides for a fixed point of operation of the circuits controlled by the hatch automatics, therefore they will always operate at the same distance from the terminal landings regardless of the stretch or slippage of ropes, thus eliminating the frequent

adjustments necessary with the machine automatics as is required on drum-type machines.

In the traction-type machine, if the safeties set, the cables will not become slack, therefore means other than a slack cable switch must be provided to stop the motor when the car safeties operate For this purpose a car-safety operated switch located under the car is used and is connected mechanically so that the action of the safeties in setting will open a contact and cause the direction and potential switches to open. In some cases the substitute for the slack cable switch is placed on the safety governor

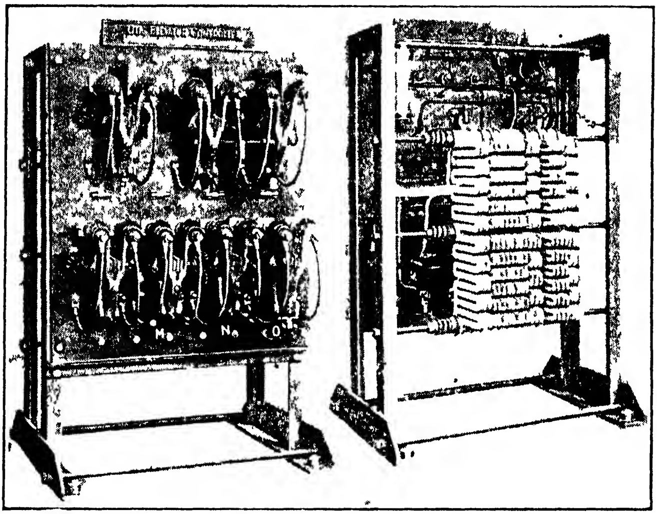


Fig. 184.—Front and back views of Otis type 2-SS alternating-current magnet elevator controller.

An Otis single-wrap traction-type elevator machine is shown in Fig. 181. This machine is driven by a single-speed slip-ring type motor, and equipped with a magnet brake. The general arrangement of this machine is as compact, accessible and substantial as the direct-current machine. The controller does not differ materially from that used with the drum-type machine. The method of wiring the operating circuits from the controller to the car switch and safety devices differs from that for the drum-type and is considered in subsequent paragraphs.

Limit Switches in Hoistway.—To provide stopping of the elevator at the terminals of the travel independently of the operator,

hoistway automatics are used. The hatchway automatic in this case consists of a cam mounted upon the car and located so that the limit switches (Figs. 182 and 183) provided at the terminals of travel will be opened. Figure 182 is a two-pole switch utilized to open two circuits, and Fig. 183 a single-pole switch opening one circuit. Each circuit is opened at two points to provide a positive opening. One each of these limit switches is provided at each terminal landing in the hatch. The first to open is the two-pole

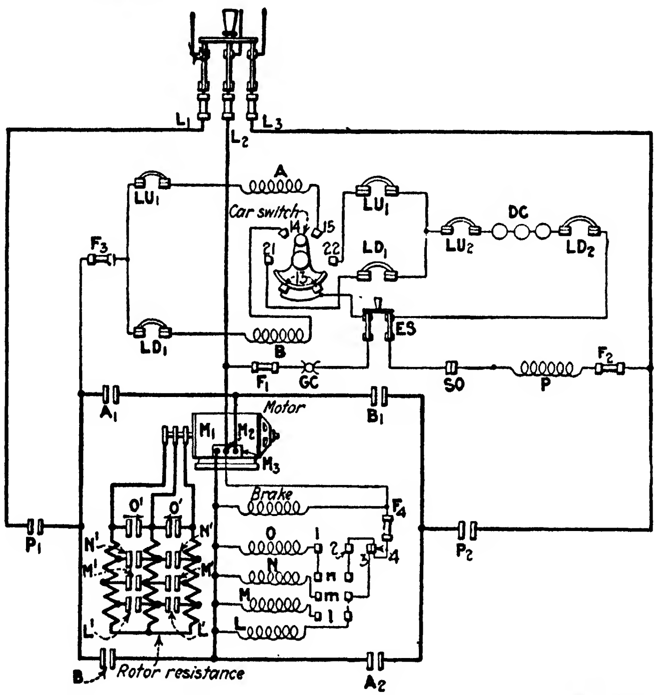


FIG. 185.—Simplified diagram of Fig. 187; car switch in off position.

switch and the second (final) is the single-pole switch. In the simplified wiring diagram, Fig. 185, the first limit switch to open at the top landing is marked LU_1, the second LU_2.

When approaching the terminal landing at the top the two-pole limit opens LU_1 contacts, releasing the up-direction switch magnet A, which will open contacts A_1 and A_2, and at the same time releases the potential-switch magnet P, which will open contacts P_1 and P_2. When starting, if the potential switch P fails to operate and close contacts P_1 and P_2, the elevator cannot be

started in either direction, since the circuits for the direction magnets are through contacts P_1 and P_2. Should the car slide above the top terminal landing sufficiently to open the single-pole limit LU_2, it will be impossible to obtain a completed circuit through the potential-switch magnet P until the car is lowered either by hand or from the controller, a distance sufficient to permit LU_2 to close. Although the two-pole limit switch on the up motion opens the potential-switch magnet circuit, the circuit is divided

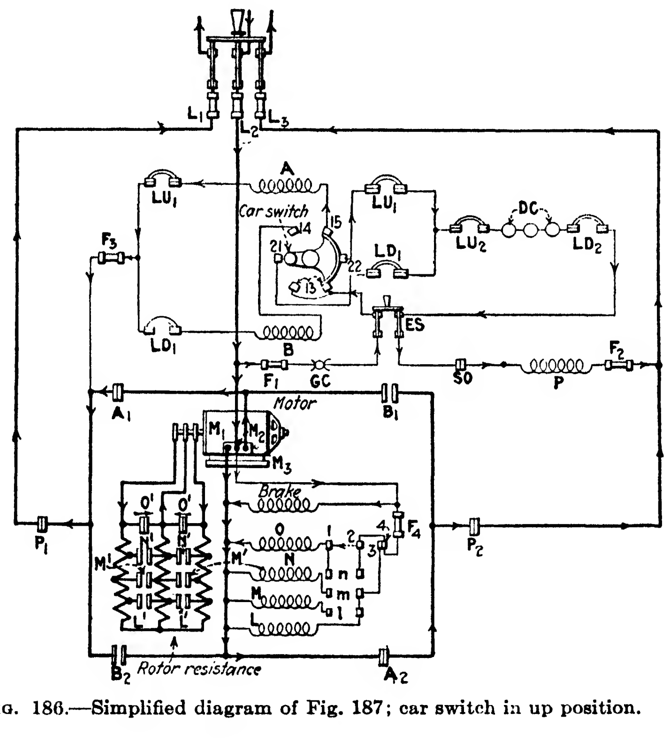


FIG. 186.—Simplified diagram of Fig. 187; car switch in up position.

through the car switch so that in the opposite direction of travel the circuit to the potential switch can be completed, passing through the two-pole limit switch at the other end of the travel.

Operation of Controller Explained.—Figure 185 is a simplified diagram of the motor and controller, which indicates the condition of the circuits with the main-line switch closed and the car-switch control handle in the center position. Under this condition all circuits are open through the controller. To run the car in the up direction the car-switch handle is moved to the left,

as in Fig. 186. The car switch will always be in contact with one of the fingers 13. When the car switch engages contact finger 22, the circuit is completed to the potential-switch magnet coil P, from line L_2 through fuse F_1, gate contact GC to 13 and 22 on the car switch, one pole of top limit switch LU_1, top limit LU_2, door contacts DC, bottom shaft limit LD_2, emergency switch ES, car-safety switch or governor switch SO, potential-switch coil P, fuse F_2 back to the L_3 side of the line. Energizing magnet coil P causes contacts P_1 and P_2 to close and complete the circuit for the up-direction magnet coil A. This circuit is from contact 15 on the car switch through coil A, the other pole of the top limit switch LU_1, fuse F_3 contact P_1 of the potential switch and to the L_1 side of the line. This energizes coil A and causes it to close contacts A_1 and A_2, which completes the motor, brake and accelerating coil L circuits. The brake circuit is from M_2 on the motor through the brake coil, contacts A_2 and P_2 to the L_3 side of the line.

Energizing the brake coil releases the brake and allows the motor to start the machine. There are two circuits through the motor's stator winding, one from M_2 to M_3 through contacts A_1 and P_1 to the L_1 side of the line, while the other circuit is from M_2 to M_1 through contacts A_2 and P_2 to the L_3 side of the line. This causes the motor to start with all the rotor resistance in circuit. Contacts L', M', N' and O' on the rotor resistance are closed by coils L, M, N and O respectively. Coil L is the first to be energized and the circuit is from M_2, through fuse F_4, coil L, contacts A_2 and P_2 to the L_3 side of the line. This causes contactor L' to close and cut out the bottom sections of the rotor resistance.

When contactor L' closes, Fig. 186, it also closes an auxiliary contact l, which completes the circuit through coil M and closes contactor M' and cuts out another section of the rotor resistance. On closing, contactor M closes auxiliary contacts m and completes the circuit through coil N and closes contactor N' and cuts out another section of the rotor resistance. When contactor N closes, it also closes auxiliary contact n and completes the circuit through coil O and closes contactor O', cuts the last section of the rotor resistance out and causes the motor to come up to full speed. When contactor O closes, it closes auxiliary contacts 1 and 2 and opens auxiliary contacts 3 and 4. The opening of contacts 3 and 4 immediately releases L and M accelerating magnets, the releasing of accelerating magnet M opens the auxiliary contactor

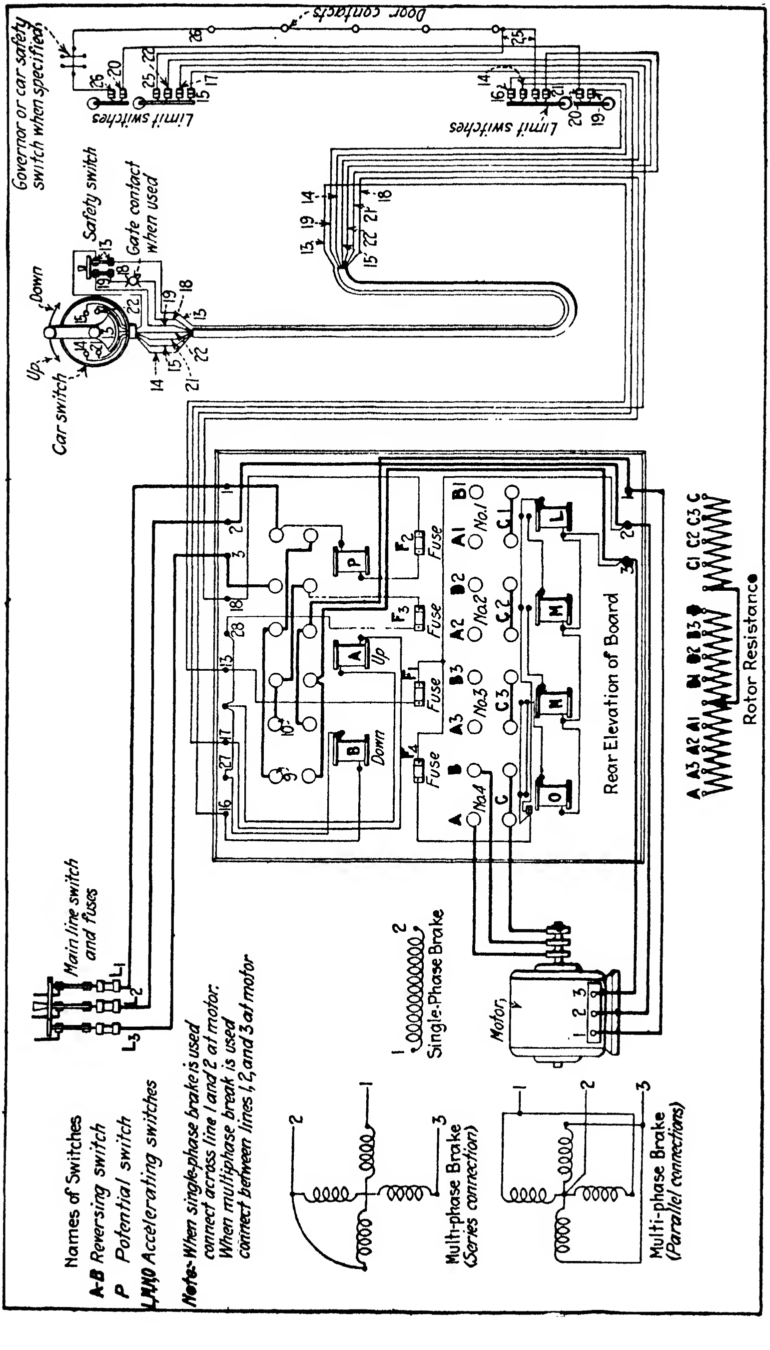


FIG. 187.—Wiring diagram for controller Fig. 184.

mounted upon it for coil *N* which also releases, so that when the motor is running at full speed the only contactor closed is *O′*, and this is held closed by coil *O* through auxiliary contacts shown at 1 and 2.

Comparison of Controllers for Drum and Traction Type of Machines.—It will be noted from the foregoing that the operation of the motor, brake and accelerating magnets is identical with the operation of the drum-type machine with the exception that the main-line current does not pass through the automatic-limit contacts as with the drum machine. The connections for the accelerating magnets shown in Figs. 185 and 186 are the better arrangement and subject to less trouble. Auxiliary contacts marked *l*, *m* and *n* are mounted on the auxiliary accelerating magnets, *L*, *M* and *N* respectively. The last, or final, accelerating magnet *O* has a make-and-break contact mounted upon it which provides for permitting magnet *O* to become self-holding, at the same time releasing auxiliary accelerating magnets *L*, *M* and *N* as previously explained.

Figure 187 is a standard wiring diagram of the control and motor wiring as supplied by the Otis Elevator Company. For those who wish to do so, the circuits on the simplified diagram, Figs. 185 and 186, can be easily identified on Fig. 187 and traced out in the same way as for Fig. 186. The rotor resistance is not connected, but its terminals are lettered to indicate the way in which they connect to the contactors. The various contactors on Fig. 187 are also indicated on Fig. 184. It will be noticed that they are in the reverse order on the diagram to what they are on the photograph. This is due to the diagram showing a rear view of the controller.

CHAPTER XIII

TWO-SPEED SQUIRREL-CAGE MOTOR CONTROLLERS

Limitations of the Single-speed Motor.—For the elevator operator to make a good landing, it is necessary that the speed of the car be decreased to about 75 ft. per minute before centering the car switch. With direct-current equipment the control can be easily arranged for slowing down the motor. On modern alternating-current elevators squirrel-cage motors are used almost exclusively, and these motors are inherently constant-speed machines. Therefore, they are limited to car speeds of 100 ft. per minute or less. For higher speed it is general practice to use two-speed squirrel-cage motors, the speed of the slow-speed motor being such as to give a satisfactory car speed for stopping the car and the high-speed motor giving the desired running car speed.

Types of Two-speed Squirrel-cage Motors.—Three types of two-speed squirrel-cage motors are used. In one type, only a single winding is used and this winding is regrouped to give to different numbers of poles; for example, 12 poles on 60-cycle for a motor speed of 600 r.p.m., and 6 poles for 1,200 r.p.m. These are theoretical speeds; the actual speeds will be about 20 per cent less.

A second method of obtaining two speeds is to put two windings in the same stator core, each grouped for a different number of poles. A third method is to use two separate stators, each wound from a different number of poles. These stators are supported in a common frame, and the rotor for each is mounted on a common shaft; thus, the two machines are combined into a single unit. The last two methods allow of most any speed ratio between the two windings, where the first is practically limited to a ratio of 1 to 2. Where two separate stator windings are used, speed ratios as high as 1 to 6 have been utilized.

Controller Operation.—A Gurney Elevator Co. type No. 32-G two-speed squirrel-cage motor controller is shown in Fig. 188. What the different contactors are used for is indicated below the figure, and the operation of the controller will be made clear by a

study of the wiring diagrams Figs. 189 and 190. Figure 189 shows the wiring diagram complete for a two-phase motor as used on a traction elevator machine, and Fig. 189 is a simplified arrangement of the connections.

On the car switch there are five connections 1, 2, 3, 4 and 5. With the car switch closed to the slow up-direction position, the

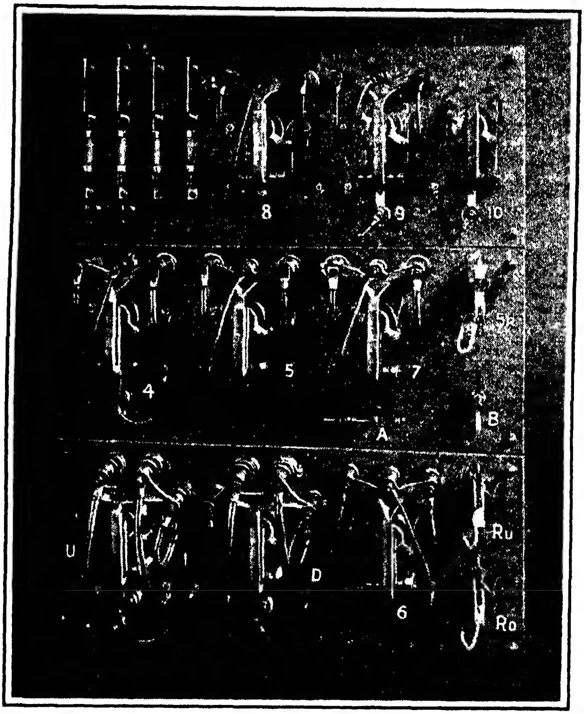


FIG. 188.—Controller for two-speed squirrel-cage induction motor.

Contactors U and D are the direction switches; contactor 4 short-circuits to high-speed motor winding; contactor 5 short-circuits the low-speed motor winding; contactor 6 short-circuits the buffer resistance; contactors 7, 8 and 9 cut out the starting resistance; relay 10 is a speed-changing interlock; relay $5R$ is a high-speed interlock; RU and RD are direction-switch interlocks; A is the throw-over control switch; B a control switch which allows operating the elevator at slow speed from the control board.

circuit is closed between points 1 and 2. This completes a circuit for the up-direction switch U from L_1 side of the line switch to the throw-over single-pole knife switch A, to No. 1 terminal at the bottom of the controller and to Nos. 1 and 2 on the car switch. From the car switch the circuit is back to 2 on the up-direction switch. Here the circuit divides, one branch being through coil

U to contact 8 on the bottom of the down-direction switch and the other through coil RU to contact 8, hence these two coils are connected in parallel. From contact 8 the circuit is through the top hoistway limit switch 8-11 and back to 11 at the bottom of the controller and to the bottom contact on contactor No. 9, through the phase-reversal relay to contact 6 at the bottom of the controller, back to the car and through the gate, safety and emergency switches, returning to 7 at the bottom of the controller and to the L_2 line terminal. This circuit can be easily traced in a simplified diagram, Fig. 190. Completing this circuit energizes the coil on the up-direction switch U and the coil on relay RU and causes the contactors to close.

With the up-direction switch closed, a circuit for the stator winding is completed from the L_1 side of the line to the top contact of switch U to 10 and to R_4, through all the resistance to T_1 and to T_1 on the motor, through the high-speed winding to T_3, and through the low-speed winding to T_{13}, back to T_{13} on the up-direction switch to the L_2 line. The circuit on the other phase of the motor is from the L_3 line to R_8 on the starting resistance, through all this resistance to T_2 on the motor, through the high-speed winding to the T_{12} terminal, through the low-speed winding to T_{14} on the up-direction switch and to the L_4 line. This connects the motor to the line with all the resistance in series with the two windings in series.

The brake coil connects to terminal 10 on the up-direction switch and T_{13} on the down-direction switch. These two terminals are energized with the closing of either direction switch and the brake is released. Referring to Fig. 190, it will be seen that the brake coil is connected directly across one of the windings of the motor and its starting resistance. This leaves the brake coil connected to the motor after it is disconnected from the line. The voltage generated in the motor winding for a short period after being disconnected from the line, helps to prevent the brake from slamming on the wheel and causing an abrupt action in stopping the car.

At the same time the up-direction switch coil was energized, the coil of relay RU was energized and its contactor closed. Closing of contactor RU completes the circuit for the coil of contactor 6, from L_1 line to the contact at the bottom of contactor 10, through RU contactor, the coil on No. 6 contactor, then through the gate, safety and emergency switches in the car and

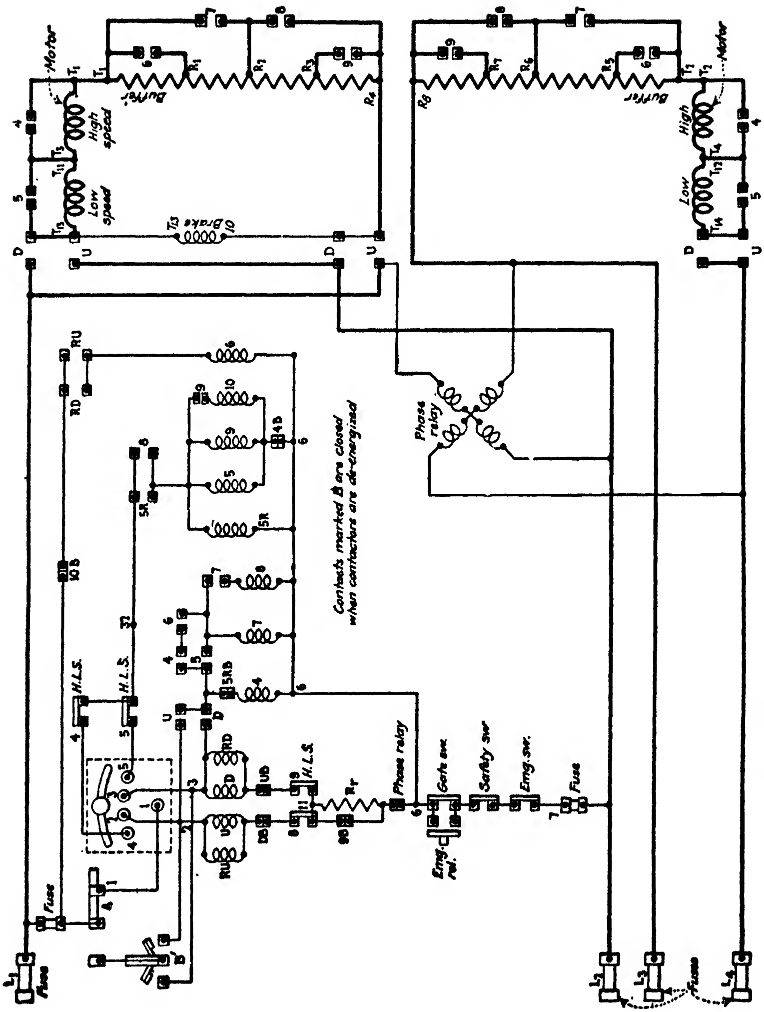


FIG. 190.—Simplified diagram of the connections, Fig. 189.

returns to the L_2 line terminal. This circuit can be easily followed on the simplified diagram Fig. 190. Closing contactor No. 6 short-circuits the buffer resistance out of each phase of the motor, by connecting T_1 of one phase to R_1 in one resistance group and T_2 of the other phase to R_5 in the other resistance group. This contactor should be adjusted to close at practically the same time the direction switch closes, since it cuts the buffer resistance out of circuit. This resistance is not intended to control the starting of the motor, but to regulate the slowdown, from high to low speed, at stopping.

Closing of contact 5′ on the up-direction switch completed the circuit for the coil on contactor No. 4, from 2 on the up-direction switch to 5′, through the bottom contact on relay $5R$, through the coil on 4 contactor to 6 terminal and returns to the L_2 line as previously explained. When contactor No. 4 closes, its two outside contacts short-circuit the high-speed winding in each phase of the motor. On the motor it will be seen that T_1 and T_3 are the terminals of one phase of the high-speed winding and T_2 and T_4 are the terminals of the other phase. When contactor 4 closes, it connects T_1 to T_3 and T_2 to T_4, thus short-circuiting the high-speed winding. This contactor should be adjusted for rapid closing so as to cut out the high-speed winding about the time that the motor begins to move.

Closing of contactor No. 4 provides a circuit for the coil on No. 7. This circuit is from 5′ on the up-direction switch through the center contacts on Nos. 4 and 6 contactors and coil 7, to terminal 6 and to the L_2 line as previously explained. Closing of this contactor connects motor terminal T_1 to resistance terminal R_2 and motor terminal T_2 to resistance terminal R_6, thus short-circuiting the resistance between these two points. It will be noted that the closing of contactor No. 7 also short-circuits contactor No. 6, which closed to cut the buffer resistance out of circuit.

Contactor No. 8 is the next to close, and a circuit for its coil is made from 5′ on the up-direction switch through the center contacts on contactors Nos. 4, 6 and 7, through coil 8, to terminal 6 and to the L_2 side of the line. Closing of this contactor short-circuits the starting resistance between R_2 and R_4 and between R_6 and R_8. This short-circuits all the starting resistance and the motor can come up to speed on the slow-speed winding.

Moving the car switch to point 4 closes the contactors to cut the high-speed windings of the motor in and the low-speed out. The first circuit is that for relay $5R$. This circuit is from 4 on the car switch to 4 at the bottom of the panel, to the lower top limit switch in the hoistway, back to 32 contact at the top of contactor 8, through the coil of relay $5R$ to 6 and to the L_2 line. When this relay closes, it completes a lock circuit to hold it closed, by connecting its terminal 32 to 3′. This allows contactor 8 to open without interfering with the operation of relay $5R$.

When relay $5R$ closed, it opened its bottom contact and interrupted the circuit through the coil of contactor No. 4 and caused this contactor to open. When this contactor opens, the high-speed winding is again cut into circuit along with the low-speed winding. Opening of No. 4 contactor also interrupts the circuits to the coils on contactors No. 7 and 8 and these contactors open, which places all the starting resistance back into the circuit.

No. 4 contactor, when it opened, closed its bottom contact 6, and this completed the circuit for the closing coils on contactors Nos. 5 and 9. The circuit for No. 5 coil is from 32 to 3′ contact on relay $5R$, through coil 5 to contact 6 on contactor No. 4 and to the L_2 line. Closing No. 5 contactor, connects T_{12} terminal of the slow-speed winding to the T_{14} terminal and the T_{11} terminal to the T_{13} terminal, thus short-circuiting the low-speed winding.

The circuit for No. 9 coil is also from the top contacts of $5R$ relay to No. 6 contact of contactor No. 4. When No. 9 contactor closes, it short-circuits the sections of starting resistance between R_3 and R_4 and between R_7 and R_8, thus increasing the speed of the motor on the high-speed winding. Bottom contact 11 on No. 9 contactor, opened when this contactor closed and placed resistance R_r in series with the coils of the up-direction switch and relay RU. This reduces the current in these coils to a value necessary to hold the contactors closed, and allows them to open more quickly when the coil circuits are interrupted, than if the current remained at the value necessary for closing.

A circuit for the coil on No. 7 contactor was completed when No. 5 contactor closed, from 5′ on the up-direction switch to the center top contact of No. 5 contactor, through coil 7 to terminal 6 and to the L_2 side of the line. Energizing of this coil causes contactor No. 7 to close and short-circuit the resistance between T_1 and R_2 and between T_2 and R_6, which further increases the speed of the motor.

The coil on No. 8 contactor is again energized, when No. 7 closes, by a circuit from terminal 7′ on contactor 7, through coil 8 to terminal 6 and the L_2 side of the line. When this contactor closes, it connects R_2 to R_4 and R_6 to R_8, thus cutting the remainder of the starting resistance out of circuit and allows the motor to come up to full speed.

No. 9 contactor closing, completes the circuit for the coil on relay 10. This circuit is from 32 and 3′ on relay 5*R*, through the center contacts of contactor No. 9, coil 10 to 6 terminal and the L_2 line. No. 10 relay has only one contact and this is normally closed. Energizing coil 10 opens this contact and interrupts the circuit to contactor No. 6. This operation causes No. 6 contactor to open and place the buffer resistance in series with the starting resistance so as to be available for slowing down the speed of the motor during the stopping operation. The buffer resistance is still cut out of the motor circuit owing to No. 7 contactor being closed.

Contactor Adjustments.—In adjusting the closing sequence and time of closing of the contactors during acceleration on the high-speed winding, No. 5 closes first and its motion should not be retarded as it short-circuits the low-speed winding in the motor. Following the closing of No. 5, contactors Nos. 9, 7, 10 and 8 close in sequence, and all should have their motion retarded by their dashpots. In adjusting these contactors, it is necessary that No. 7 closes before No. 10 opens its contact, to prevent cutting the buffer resistance into circuit with the motor. All the contactors on the controller are equipped with a dashpot for adjusting their time of closing, with the exception of contactors 5*R*, *RU* and *RD*.

Slow-down Operation.—To slow down the speed of the car preparatory to stopping, the operator moves the car switch from contact 4 back to contact 2. This interrupts the circuit to relays 5*R* and 10 and to contactors 5 and 9, which causes these to open. When No. 5 opens, it puts the low-speed winding back into circuit and interrupts the circuit to the closing coils of contactors 7 and 8. This causes these contactors to open and connects all the resistance between T_1 and R_4 and between T_2 and R_8 in series with the two windings of the motor. Opening of relay 5*R* closes its contactor No. 4, which causes this contactor to close and short-circuits the high-speed winding.

The motor is now operating on the low-speed winding at a speed higher than that corresponding to this winding, conse-

quently the motor is converted into an induction generator and supplies a current to the power system. This action causes the motor to produce a retarding action to slow down the machine. The buffer resistance is connected in series with the starting resistance to prevent the slowing-down action of the motor being too abrupt. When No. 10 relay closes its bottom contact, it completes a circuit for the coil on contactor No. 6, which closes and short-circuits the buffer resistance after the motor has partly slowed down. Cutting out the buffer resistance helps to maintain the retarding action of the motor at a value that will slow the car down in a minimum of time, without any disagreeable effects on the passengers. The time of closing of No. 6 contactors is controlled by the opening time of relay 10, which is regulated by a dashpot.

A circuit was made for the coil on No. 7 contactor, when Nos. 4 and 6 closed, which causes No. 7 to close and short-circuit the resistance between T_1 and R_2 and between T_2 and R_6. This operation tends further to maintain the retarding action of the motor. When contactor No. 7 closed its center contact, it completed a circuit for the closing coil of No. 8 contactor, which closes and cuts out the remainder of the starting resistance and the motor slows down to a speed corresponding to that of the slow-speed winding.

The final stopping of the car is completed by the operator bringing the car switch to the off position, when all contactors come to their off position, cutting the power out of the motor entirely and releasing the mechanical brake, which is applied by springs.

At the top floor the car is stopped automatically by the limit switches in the hoistway, first by 4-32 opening and switching in the slow-speed winding and short-circuiting the high-speed winding. The final stop is made by limit 8-11 opening, which performs the same function as moving the car switch from No. 2 to the off position.

In the down direction the sequence of events is the same except that the car switch is moved to points 3 and 5 and the down-direction contactor and *RD* relay close instead of the up-direction contactor and relay *RU*.

When tracing out the various circuits Fig. 189, the simplified diagram Fig. 190 will be of assistance in following out these circuits and seeing just what takes place when the various contactors function.

CHAPTER XIV

PUSH BUTTON AND DUAL CONTROL

Constant-pressure Push-button Type.—Elevators controlled from push buttons are coming into general use for many applications. One of the applications is where the car is used infrequently and it is not desired to keep an operator on it, such as in slow-speed freight service in certain classes of buildings with open-hoistway construction where the position of the car can be observed from the landings. Many of these installations were formerly hand-rope operated, and it always was a serious hazard reaching into the elevator hoistway to pull on the rope to bring the elevator to the floor and stop it. To meet the requirements of this service, a control has been developed known as the constant-pressure push-button type, which permits operation from either the floor landings or the car by push buttons. The push button must be held closed as long as it is desired for the car to stay in motion, and it is stopped by releasing the button. The control is what might be considered a car-switch type modified for the use of push buttons, to allow control from the landings as well as from the car.

Figure 191 is a wiring diagram of a Westinghouse controller of the constant-pressure push-button type. This diagram is for a three-floor control, although any number of floors may be connected.

For the three-floor control there is an up- and a down-direction button in the car and likewise at the intermediate floor. At the bottom terminal landing there is a down-direction button, which will permit bringing the car to that floor by pushing the button. At the top terminal landing there is a button, which, when pressed, will bring the car to that floor. When there are more than three floors, at each intermediate floor there are two buttons, one to bring the car down and the other to bring it up, connected as indicated in Fig. 191.

Tracing out the circuits of the diagram will make clear the operation of the controller. The control circuit is from line L_1

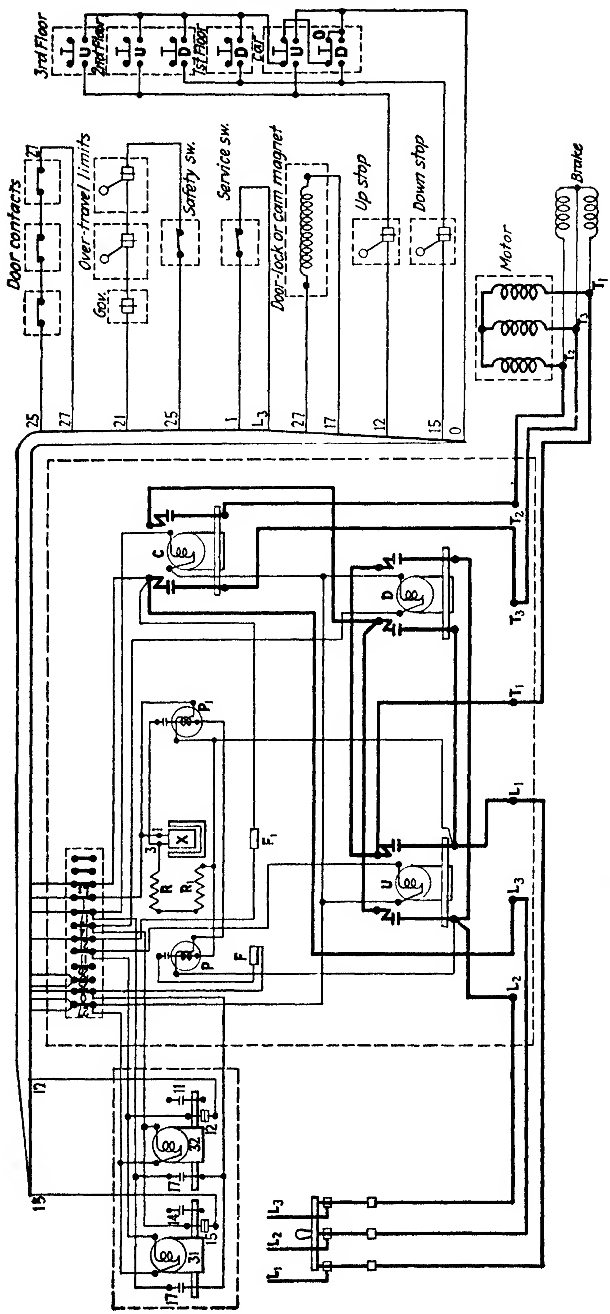


FIG. 191.—Diagram of constant-pressure push-button type elevator controller.

through the contact of reverse-phase relay *P* to terminal *O* and to *O* on the push buttons. It will be seen that this wire runs to all the push buttons, so that if either an up- or a down-direction button is pressed, either the up- or the down-direction circuit will be made alive if the conditions of the circuit for safe operation are complied with.

Assume that the bottom button *D*, which is the down button in the car, is pressed. This completes the circuit through the down stop switch to contact 15 on relay 31. This contact being closed, the circuit is to terminal 14, the down-direction switch coil *D* to terminal 27, through the door contacts back to terminal 25, then through the safety, overtravel-limit and governor switches to terminal 21 and the L_3 line. This energizes the down-direction switch coil and this contactor closes. At the same time that this operation has been going on, the coil of relay 32 is energized from contact 15, through coil 32 to terminal 27, through the door contacts and to the L_3 line as previously explained. From the foregoing it is evident that unless the door contacts are closed, the direction-switch on the relay coil cannot be energized. The construction of the door locks is such that the doors must be closed and locked before the contacts can close. Therefore it will not be possible to start the car before the doors have been closed and locked.

Making the coil of relay 32 alive causes this relay to close. In doing so, it opens contact 12, which opens the up-direction switch coil circuit so that this switch cannot be closed by pushing an up-direction button while the down-direction button is held closed. When relay 32 closes, it makes contact 17, which completes the circuits for the door lock or cam magnets and for the line contactor coil *C*.

Operation of the Door Locks.—On some types of door locks there is a magnet coil in each lock. These magnets are connected to the lock mechanism in such a way that the doors cannot be opened as long as the magnets are energized. Even when the coils are not energized, the doors cannot be unlocked and opened except when the car is stopped level at the floor. A cam installed on the car is so placed that it holds up a lever on the lock, when the car is stopped at a floor, that allows the door to be opened when the magnet in the lock is de-energized.

On another type of lock a magnet is put on the cam on the car, which raises the lock lever to allow the door to be opened. With

this arrangement the magnet is used to pull the cam to a position where it cannot lift the lever on the locks when the car is in motion, and allow the doors to be opened. This also prevents a door from being opened unless the car is at the floor and the cam magnet de-energized, which means that the control circuits must be dead.

With relay 32 closed, the door-lock magnet coils are energized from O through contact 17, through these magnet coils to terminal 27 and to L_3 line, as previously explained. This completes the locking operation of the door at the floor where the car is standing. From 17 there is also a circuit through coil C of the line contactor to terminal 27 and to line L_3 as was traced for the direction-switch coil. With coil C made alive, this switch closes and the motor starts, the brake coils being made alive with the motor. The elevator will now keep in motion as long as button D is held closed. Releasing the button will stop the car, or if the button is held closed until the down terminal landing is reached, the down stop switch will be opened and the car stopped. If this switch fails, the overtravel-limit switches will be opened and interrupt all the control circuits.

The circuits just described would be made alive by pressing any one of the other down buttons. For example, pressing the second-floor down button the circuit would be from O through the down and the up buttons in the car and through the down button at the second floor and to the down stop switch. From here the circuits are as previously described.

For up direction, one of the up buttons is pressed, which energizes the circuits to start the car in this direction. These circuits may be traced in the same way as explained for the down direction. In this case it will be found that direction switch coil U will be energized instead of coil D and relay coil 31 will be made alive instead of coil 32.

Two-floor Automatic Control.—Where the elevator has a lift of one floor only, such as for sidewalk service, the control, Fig. 191, can be arranged so that the car will go to the floor after the button has been pressed and released. The diagram Fig. 192 shows the control Fig. 191 arranged for two-floor automatic operation. In these connections there are three buttons in the car, up U, down D and stop. This stop button, it will be seen, is in series with the overtravel-limit switches. When this button is pressed, it interrupts all the control circuits, the same as the over-

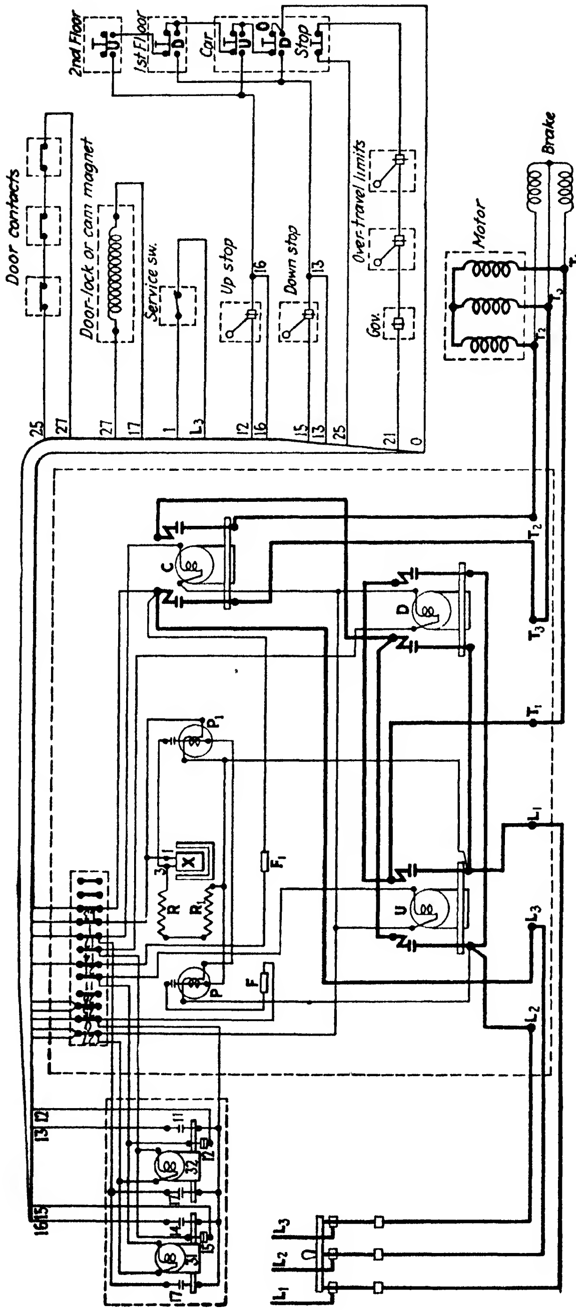


FIG. 192.—Diagram of two-floor automatic push-button type elevator controller.

travel limits do when they are opened. The purpose of the stop button is to allow stopping the car, by someone on it, before coming to the floor it was started for, should such occasion arise.

As there are only two floors, only one button is required at each. At the upper floor is the up button U, which, when pressed, will cause the car to come from the lower floor to the upper. Pressing the down button will bring the car from the upper floor to the lower. In Fig. 192, as in Fig. 191, the control circuit is from line L_1 to the down button D in the car. From this button the line continues to all the buttons. Assume that the car is at the upper floor and the down button is pressed. This completes the circuits through the down-stop switch through the down-direction switch coil D, and relay coil 32, as explained for Fig. 191. When relay 32 closes, it also completes the circuits for the cam or door-lock magnets and the line-switch coil C through contact 17, as in Fig. 191.

So far the operation of the controller is identical with Fig. 191. In Fig. 192, when relay 32 closes it makes a holding circuit through its contact 11. This circuit is from line O through contact 11 on relay 32 to 13 on the right of the down stop switch, then through this switch and will maintain the control circuits alive when button D in the car is released. Therefore, after relay 32 closes, the down button may be released and have the car go to the lower floor. On approaching this floor the down-stop switch is opened by a cam on the car and the machine is stopped with the car at the floor, if everything is working properly.

In the up direction the operation is the same as in the down, except circuits are established for up-direction switch coil U and the coil of relay 31, instead of coils D and 32. Where more than two floors are involved, floor selector switches and other refinements must be incorporated in the control system if it is to provide automatic control of the elevator.

Dual Control.—Full magnet type elevator control may be divided into three general classes: Car-switch; push-button, or automatic; and a combination of the two, dual control. There are many places, such as hospitals, small hotels and apartment houses, and some classes of industrial buildings, where during certain periods of the day the traffic is heavy enough to justify having an operator on the car. At other times there is little use for the elevator, but it will be required by people on the different floors of the building.

The first of these requirements is taken care of by car-switch control and the latter by push-button or automatic control. In a dual system, the part of the control equipment used for starting, stopping and reversing the motor is common to both car-switch and push-button operation. The dual system may be considered a car-switch type of control, with the push-button system added.

On the car-switch control the operator starts and stops the car by manipulating the control with the car switch. At the terminal landings a limit stop is provided that will cause the control to function and stop the car if the operator fails to center the car switch. Should these two fail and the car pass the floor a short distance, a final switch is opened to cause the machine to stop. In the automatic push-button system of control means are provided, if all the requirements for safe operation are complied with, to start the elevator and bring it to a stop at a floor by pushing a button. After pushing the button, it can be released and the rest of the control is automatic and is effected by the use of a floor-selector switch and floor-selector relays.

The floor-selector switch has a rotating member which is driven from the machine and opens contact as the car approaches the different floors. When the car approaches the floor corresponding to the starting button, the floor-selector switch opens a contact that causes the control to function and stops the car at that floor. A Cutler-Hammer dual controller panel for a squirrel-cage induction motor is shown in Fig. 193. The different parts of the controller are indicated below the figure. A wiring diagram for this type of controller, but with the transfer switch in the car, is presented in Fig. 194. The following description of the controller's operation will bring out the various functions performed:

Car-switch Operation.—In describing the controller, operation from the car switch will first be considered and the circuits for push-button operation then explained. The control circuit starts from L_2 terminal on the control panel and passes through the fuse F into the cable and to the N_2 terminal at the top of the controller. From N_2 terminal the circuit continues to the junction box on the controller, then to the up overtravel-limit switch, through the hoist-way junction box, to N_1 on the down overtravel-limit switch, then back to the hoistway junction box and to the junction box on the car. From the junction box on the car this circuit is to N on the transfer switch, which in this case is shown in the car. The dotted lines show the position of the transfer

switch for car-switch operation. Therefore, from N on the transfer switch the circuit is to C and returns to C on the car switch.

Assume that the car switch is moved to the down position; then it will close the circuit between C and 1. From 1 on the car switch, the circuit leads to the junction box in the hoistway and to the down terminal limit switch and returns to 11 on direction relay DR on the controller. The circuit is then through coil D on the down-direction switch, resistance E to terminal X, and returns to X on the car safety switch, through this switch, the car-door contact, stop button in the car, to X_3 and X_4 on the down overtravel-limit switch, through the door safety switches, to the up overtravel-limit switch, the governor switch, to X_{10} terminal at the top of the controller, and to the L_1 side of the line.

In the hoistway junction box a tap is taken off N, which returns to terminal N at the top of the controller and goes to auxiliary contacts D'' and U'' on the direction switches D and U and the center contacts of the test switch. All these are open, so that they can be forgotten for the present.

Energizing the down-direction-switch circuit causes coil D to close its contactor. When this contactor closes, auxiliary contacts D' open and D'' close and complete the circuit for the coil of timing relay AR. This circuit is from N on the controller, through auxiliary contacts D'' and M', through coil AR to X and to the L_1 side of the line as previously explained. Making this circuit alive causes relay AR to function and opens contact A and closes R'. This operation completes the circuit for coil M of the potential switch, from N, through contacts D'', contact R' and coil M to X, returning to the L_1 line as previously traced.

When contactor M closes, it completes the circuit for the motor from L_1 line, through the left-hand side of contactor D, starting resistance R_{11}-R_{12} to T_3 on the motor. Another motor circuit is from L_3, through the right-hand side of contactors M and D, resistance R_1-R_2 to T_1 on the motor. These circuits continue through the motor and return from T_2, through the left-hand side of potential switch M to the L_2 line. The brake torque motor is connected to the three lines and is energized when switch M closes, so that the brake is released and the motor starts with resistance R_1-R_2 and R_{11}-R_{12} in series with the stator windings.

Auxiliary contacts M' are opened and M'' closed when contactor M closes. Opening contacts M' interrupt the circuit to coil

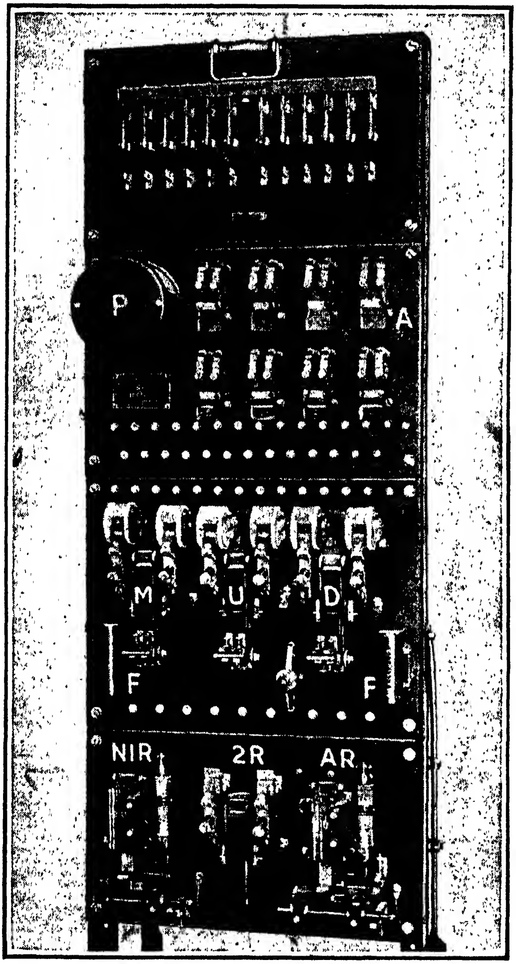


Fig. 193.—Panel board for combination car-switch and push-button alternating-current control.

For car-switch operation the multipole knife switch at the top of the panel is in the up position and for push-button control is in the down position. The group of small contactors at *A* are the direction-switch and floor-selector relays. *P* is the phase-failure and phase-reversal relay; *U* and *D*, direction switches; *M*, potential switch; 2*R*, switch to short-circuit the starting resistance; *AR*, timing relay for the 2*R* switch; *NIR*, non-interference relay; *F* and *F*, control-circuit fuses.

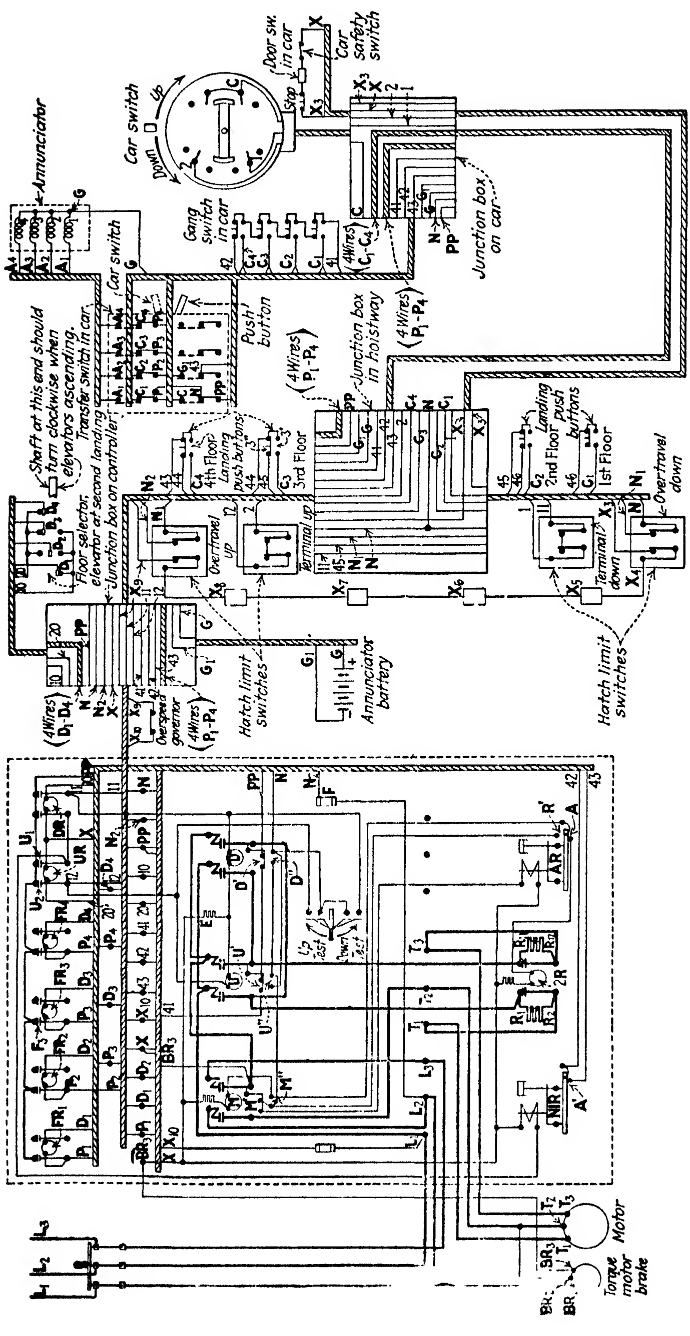


FIG. 194.—Wiring diagram of combination car-switch and push-button control for a squirrel-cage motor started through one step of resistance.

AR and this relay starts to open, but is retarded by a dashpot, so that contact R_1 remains closed for a short period. The closing of contacts M'' completes a circuit for coil M, from N through M'', coil M to X, without going through contact R', therefore, when relay AR opens contact R', potential switch M will remain closed.

On closing contact A, a circuit is made for coil $2R$ on the starting-resistance contactor. This circuit is from N, through contacts D'', M'' and A, through coil $2R$ to X and to the L_1 side of the line. Making coil $2R$ alive causes it to close its contactor and cuts resistances R_1-R_2 and R_{11}-R_{12} out of circuit and the motor comes up to full speed. The time of closing contactor $2R$ is controlled by the timing of the dashpot on relay AR.

Floor Push Button Used to Signal the Car Operator.—On this controller the push buttons at the landings are so connected that they are used for signaling the operator when the machine is under car-switch control, and bring the car to the floor when the machine is under push-button control. The terminals G and G_1 of the annunciator battery go to G on the annunciator and G_1 on the transfer switch in the car. Assume that the third-floor landing button is pushed when the machine is under car-switch control, this would close contacts 3′ and open 3″ and complete a circuit from G on the battery to G on the annunciator, through coil 3 to A_3 on the transfer switch to C_3 on the third-floor button, to 44 on the fourth-floor button, and return to 43 on the transfer switch and to G_1 on the battery. This completes the circuit to operate the third-floor call on the annunciator, as on the ordinary system of signaling the operator. The other call circuits may be traced out in the same way.

When following through the different circuits, it probably has been noticed that a number of branches extended off at various points. These have to do with the push-button control system and if followed out would be found to be open for the car-switch control.

Operation on Push-button Control.—To change from car-switch control to push-button, the only operation necessary is to throw the transfer switch, which in Fig. 193 is on the control panel and in Fig. 194 is on the car. The full-line connections between N and PP, C_1 and P_1, etc., Fig. 194, show the position of the transfer switch for push-button control, which will now be considered. The floor selector switch is shown in the position

that would obtain with the elevator at the second floor; that is, contact D_2 is open. Assume that the car is at the second floor, with the gate and doors closed, and that the landing button on the third floor is pressed, which will open contacts 3″ and close 3′ on this button.

The control circuit from L_2 on the controller to N on the transfer switch is common to both the car switch and the push buttons. From N on the transfer switch, the circuit continues to PP terminal at the top of the controller. There are two leads from this terminal, one of which goes to the top contacts of the floor selector relays, and the direction-switch relays, all of which are open.

The other branch from PP goes through the top auxiliary contacts of the direction switches to terminal 41 and returns to 41 on the push buttons in the car. From here the circuit continues through all these buttons in series and returns to terminal 42 on the controller. Continuing, the circuit passes through contact A' on relay NIR and to 43 on the fourth floor button, to 44 on the third floor button, through contacts 3′ to C_3 on the transfer switch, and returns to terminal P_3 on the controller. This circuit is completed through the coil of the floor-selector relay FR_3, to D_3 on the floor-selector switch, to 20 on the controller, through the up-direction relay coil UR and to the L_1 line as explained for the car-switch control.

Energizing the coils of relays FR_3 and UR causes these relays to close their contacts. The right-hand contact of UR closing, completes a circuit for the non-interference relay NIR. This circuit is from terminal PP at the top of the panel, right-hand contact of relay UR, through coil NIR to terminal X and to the L_1 side of the line. When this relay opens its contact A', it cuts all the push buttons out of circuit and prevents the operation of the machine being interfered with from the push buttons when the car is in motion. The push-button part of the control circuit is short-circuited by closing any one of the floor relays, in this case by closing the contact of FR_3. This completes the circuit from PP, through contact F_3, coil FR_3 to D_3 without going through the push buttons.

This operation will be more clearly seen by referring to Fig. 195, which shows the control circuit just described in simplified form with the non-interference relay contacts NIR closed. This circuit can be easily followed through from L_2 at the top of the diagram to L_1 at the bottom. Figure 196 is similar to Fig. 195,

but the F_3 and U_1 contacts are closed and A' opened. The closing of U_1 contact completes the circuit for relay coil *NIR*, and closing contact F_3 completes a circuit from *PP* to P_3, which shunts out of circuit auxiliary contacts D' and U' on the direction switches, the push buttons in the car, *NIR* relay contact A', landing push buttons, and the transfer-switch contact. Therefore, when relay FR_3 closes and *NIR* opens, further control of the car is taken away from the push buttons, so that after the car is once started from a push button it will go to that floor and stop before it can be controlled by another button. When the car stops at a floor, opening the gate will prevent starting again until the gate and landing doors are closed.

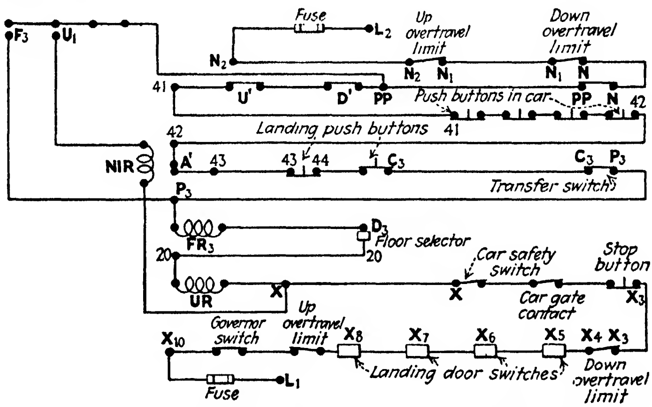


FIG. 195.—Control circuit when first completed by pushing a floor button.

Closing contact U_2 of direction relay *UR* completes the circuit for the up-direction switch coil *U*. This circuit is from *PP* through contact U_2, coil *U* of the up-direction switch, to *X* and the L_1 side of the line. Making the circuit alive causes the up-direction switch to close. Auxiliary contacts U' are opened and U'' closed, when the direction switch closes. The closing of auxiliary contacts U'' makes the circuit for timing-relay coil *AR*, from *N*, through contacts U'', and M', coil *AR* to *X*, and to the L_1 side of the line. From here on the starting of the motor is the same as explained in the car-switch control.

When the car approaches the third floor, contact D_3 on the selector switch is opened and causes the car to stop automatically at the floor. By referring to Fig. 196 it will be seen that when contact D_3 opens, it breaks the circuit through relay coils FR_3

and *UR*. When these relays open, they interrupt the circuits to up-direction switch *U* and to the non-interference relay *NIR*. On the non-interference relay there is a dashpot to delay the closing of contact *A′*. After the elevator stops, it cannot be started again until contact *A′* closes; therefore, by delaying its closing it gives those operating the car time to open the gate and door and prevent the car from being started from another push button until they are through with the car. After the landing door and gate have been closed, the car is available for someone else on another floor, or it may be boarded at the floor where it is located, the door and gate closed, and the car started to another floor by pressing the proper button in the car.

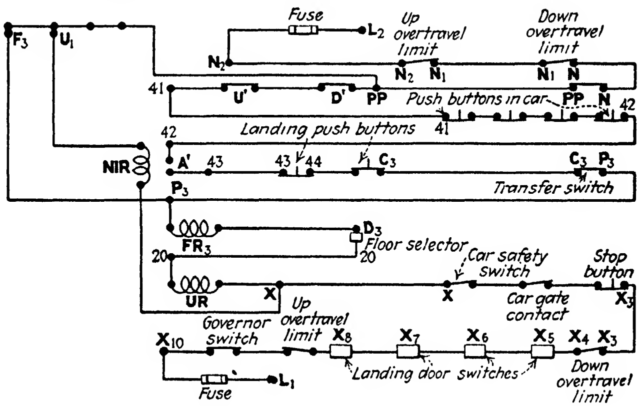


Fig. 196.—Control circuit after floor-selector, direction-switch and non-interference relays have functioned.

Connected in the control circuit in the car is a stop button, which may be used to stop the car by anyone riding in it. For example, a mistake might be made and the car started in the up-direction, when the intention was to go down. In such a case all that is necessary is to push the stop button and when the car comes to rest press the button for the desired floor.

When tracing out the control circuit for push-button operation, it was found that only the overtravel hoistway limits were included. The terminal-landing limits are used with the car-switch control only. Under automatic control the terminal-landing stops are made by the floor selector switch as are all the other floor stops. In case something happens and the car goes by a terminal landing, the overtravel-limit switch is brought into operation to stop the machine.

CHAPTER XV

CAR-SWITCH CONTROL WITH AUTOMATIC LANDING[1]

Automatic Stopping at Landings.—Many types of controls have been developed to automatically stop elevator cars level with the landings. The simpler forms function in connection with car-switch operation as does the A. B. See type L-7A, two speed. With this controller the operator starts the car as with ordinary car-switch control. A conventional flashlight signal system indicates to the operator, when the car is approaching a floor, where a waiting passenger has pressed a floor button for the direction in which the car is traveling. When a floor signal flashes, if the car switch is centered the car will slow down automatically and stops level with the floor where the signal was given. When stopping for car passengers the operator judges stopping distance as with conventional type of control and centers the car switch at the proper time, after which a stop is made automatically level with the floor.

Operation by Car Switch.—This type of control requires operation by a car switch as with usual control but relieves the operator of making floor stops. The control panel, Fig. 197, is similar to that for standard variable-voltage operation. There is also a floor-selector Fig. 198, to complete the floor stopping circuit after the car switch is centered. This selector is driven by a flat steel tape running over sheaves *S* and connecting to the car. A circular commutator *C* on top of the selector has two brushes traveling on it, one being for up motion and one for down. The commutator segments are connected in series with the selector contacts and act as a micrometer adjustment on the latter.

Figure 200 is a diagram of the control equipment. For simplicity all circuits for up direction only are included. Contactors are identified on the diagram as on control panel, Fig. 197. In the diagram most contactors are shown complete but without some of their connecting wires. These contacts without wires will be found in their circuits in other parts of the

[1] M. S. Hill assisted in writing this chapter.

diagram. This feature will become clear as the diagram is followed through.

Motor-generator Starting.—Motor-generator wiring connections appear at the top of the diagram. This set comprises a

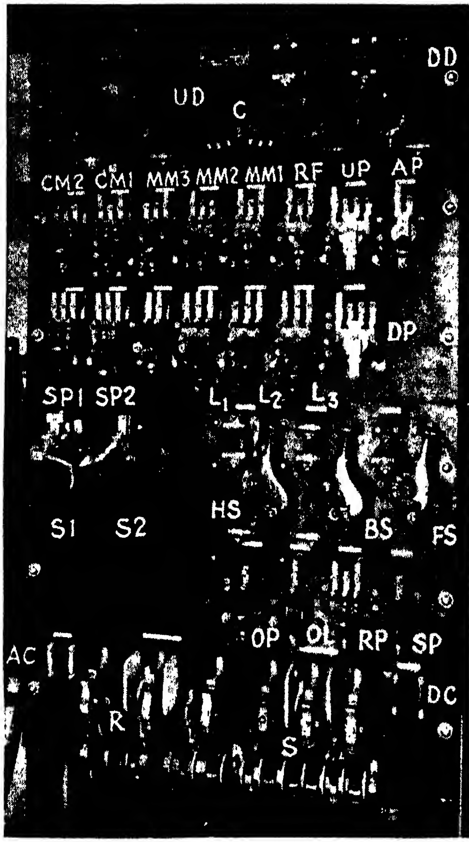


Fig. 197.

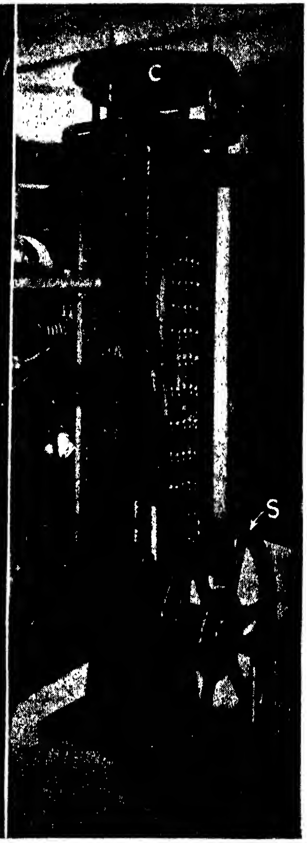


Fig. 198.

Fig. 197.—A. B. See type *L-7A* two-speed control panel.

UD, up-direction switches; *DD*, down-direction switches; *C*, control switch contacts; *UP* up pilot; *AP*, auto pilot; *SP*1, speed-pilot No. 1; *SP*2, speed-pilot No. 2; *DP* down pilot; *BS*, brake switch; *OL*, overload relay; *AC*, alternating-current fuses; *DC*, direct-current fuses; *R*, motor-running switch; *S*, motor-starting switch. The other contactors are clearly identified on Fig. 200.

Fig. 198.—Floor selector, with tape driving wheel at *S*.

small squirrel-cage motor for starting, a large squirrel-cage motor for normal running, a direct-current generator, and an exciter, Fig. 199. Initial starting and stopping is from push button in the car.

Closing the *M.-G.* switch in car, completes a circuit from line *A* through the reverse-phase relay, *M.-G.* switch in car, coil *S*, release-pilot contact B_1, run-switch contact *C*, overload-relay contact, and to line *B*. The start switch closes its auxiliary contacts *A* and A_1 and a circuit to the starting motor. The motor-generator starts and the exciter builds up voltage. The release-pilot coil *RP* and start-pilot coil *SP* are energized by the exciter, the former through the release-pilot contact *B* and the latter through the start-switch auxiliary contact *A*. The release-pilot coil opens its contacts *B* and B_1 at about 75 per cent exciter voltage, cuts resistance R_{27} in series with coil *RP*, and

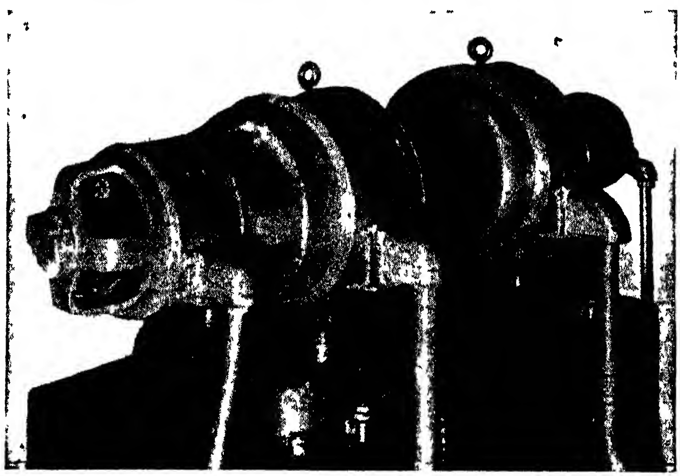


Fig 199.—Motor-generator set for the controller, Fig 197

transfers the start-coil circuit to contact A_1. The start-pilot coil closes its contact C_1 at nearly full speed of the start motor and completes a circuit for the running-contactor coil *R*.

When the run switch closes, the main motor is energized, the auxiliary contact *D* closes, and *C* opens. The latter opens the start-motor contactor-coil circuit, and this motor is disconnected. Closing of contact *D* completes the running-contactor-coil circuit directly to overload relay. The start-switch auxiliary contact *A* opens and releases the start-pilot contact C_1. When the run-switch pulls in it closes the auxiliary contact *F* and energizes the safety circuit. This circuit is from + on the exciter through the reverse field-switch coil R, door contacts, gate contacts, baby switch in the car, limit switches, counterweight, broken-tape and governor contacts, auxiliary contact *F*, and to − line.

The closing of the reverse-field switch completes the direction-switch circuit when the car switch is moved to on position and also opens its contacts *RF*. The opening of the contacts *RF* disconnects the generator shunt field from the elevator-motor armature. Up-direction contacts only are shown for the car switch in the diagram. The three right-hand contacts are in the car switch and the three left-hand contacts are on the control panel in the motor room. Assume operation in up-direction. For slow-speed, this circuit is from the + line, through the lower half of resistance R_{15}, contact M on switch MM_1, car-switch top contacts 1 and 2, up-direction switch coils, terminal-stopping switch *UR*, brake-switch coil, contact L on leveling switch 3, reverse-field switch center contact, and through safety circuit to the − line.

Energizing this circuit closes the brake and the up-direction switches. The brake circuit is from the + on the direction switch, contacts B_1 on the brake, brake coil and switch and to the − up-direction switch. When the brake is released, it opens contacts B_1 and connects resistances R_{33} and R_{32} in series with the brake coil, and it also closes contacts B_2. When the + direction switch pulls in, it closes contact *UL* and completes a circuit directly to car-switch top contact, making this circuit independent of resistance R_{15} and contactor MM_1. Coil MM_1 circuit is from the + direction switch through up-direction-switch blow-out coil *BO*, MM_1 coil, direction-switch blow-out coil BO_1 and to the − line. When MM_1 closes, it opens its top contacts and closes its bottom contacts.

The amount of resistance in the generator series-field-coil circuit is controlled by contacts S_1 and S_2. Before S_1 and S_2 close, the generator is connected shunt. A circuit for the S_1 coil with a high-speed blow-out coil in series is directly from the + to the − direction-switch terminals. Energizing this circuit closes contact S_1 and completes the circuit through generator series winding, overload-pilot coil *OP* and directly to the motor armature, with high-resistance grid G in parallel with the series winding.

The S_2 coil is in series with the elevator-motor shunt-field-switch coil *FS*. Their circuit is from the + direction switch through the two coils, contact S on the speed-pilot switch No. 2, M on MM_2 contactor, L_1 on No. 3 leveling switch, the brake switch, and to the − line. Contact S_2 closes and puts the low-

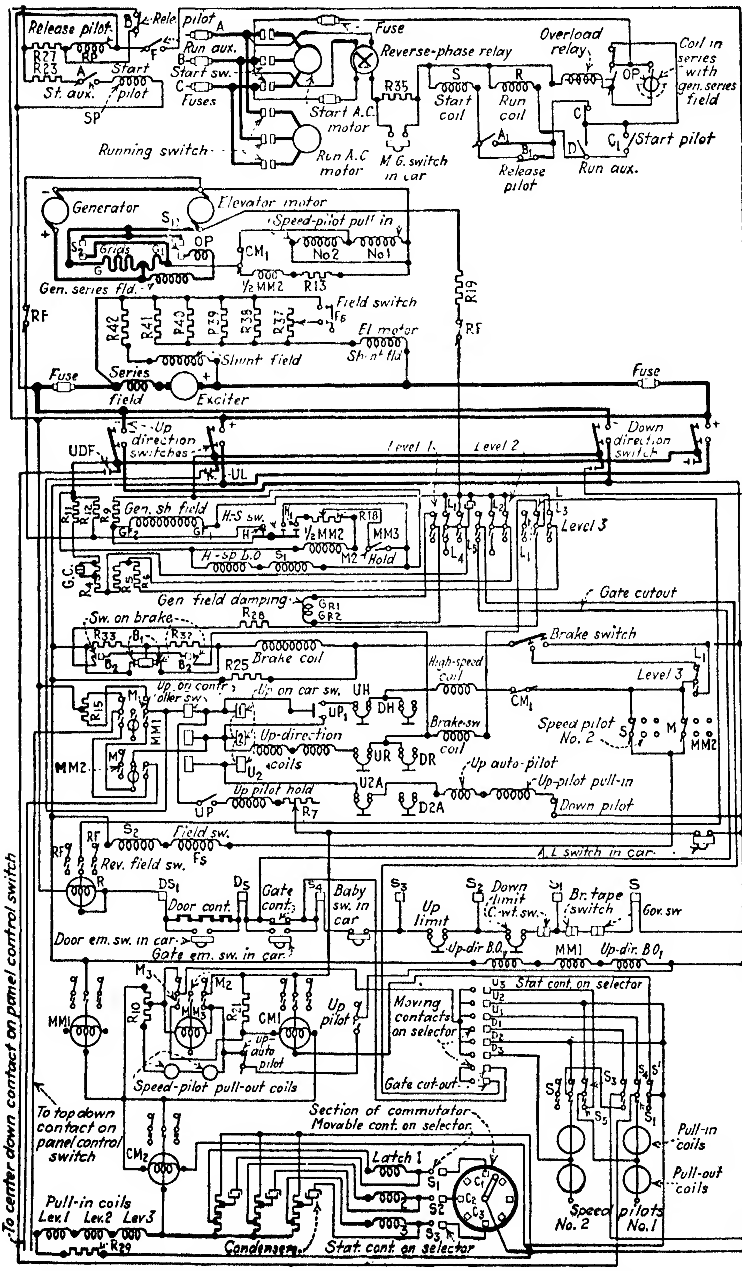


FIG. 200.—Simplified diagram of an A. B. See type *L-7A* two-speed control.

resistance grid G_1 in parallel with the generator series field. This gives a weak series field on the generator at starting. The field switch FS closes and puts low resistance R_{37} in parallel with the elevator-motor shunt-field resistance; it also gives a strong motor shunt field at starting.

Generator Shunt-field Circuit.—The generator shunt-field circuit is from the + direction switch, resistance R_9, generator-field winding, top contacts L_1 on leveling switch No. 1, part of R_4, R_{11} resistance, and to the − direction switch, giving the generator a weak shunt field for first speed. Resistance R_{12} is shunted across the generator shunt field from GF_2 to contact H on the high-speed switch and to the − line. This resistance helps to weaken the shunt field and also keeps that circuit closed during switching operations. As the field circuits are now established, the generator has a weak shunt and a series field and the elevator motor has a strong shunt field, conditions conducive to operating the motor at slow speed.

The motor-armature circuit is from the + generator armature to between grid sections G and G_1, through G to the motor armature, also G_1 and S_2 to the motor armature. A third branch is the series-field coils, overload-pilot coil OP, contact S_1 to the motor armature, and to the − on generator. The motor starts at slow speed with a strong torque. If the car switch is held on the first point, the motor will operate at slow speed. For high-speed, the car switch is moved to full-on position and energizes U_2 contact, completing a circuit through the terminal-slow-down switch $U2A$, up-auto-pilot coil, up-pilot pull-in coil, down-pilot contact, and to the − line. Making the up-pilot coil alive closes contacts UP and UP_1.

Up-pilot Holding-coil Circuit.—Contact UP closing completes a circuit for the up-pilot holding coil directly from the top contact on the operating switch, through the up-pilot holding coil, resistance R_7, automatic leveling switch AL in car, and to the − line. Closing contacts UP_1 make a circuit to the first-speed contact on the car switch so it can be centered, and the control circuits remain alive. Opening the high-speed contact on the car switch will not open the up-pilot contactor because the holding coil on this switch is alive from the + side of the direction switch. Contact UP_1 closing also makes a circuit for the high-speed coil through the limit switch UH, high-speed coil, one top contact on switch CM_1, contact L_1 on leveling switch 3, brake

switch and to − line. The high-speed switch HS closes, cuts resistance R_9 out of the generator shunt field, and disconnects shunt R_{12} from across this winding. The generator voltage increases and the elevator motor speeds up. The generator shunt-field circuit is from the + direction switch to the high-speed switch center-contact, the generator-field-winding terminal GF_2 through this winding, part of R_4, R_{11} and to the − line.

The MM_2 contactor has two coils, one of which is connected across the elevator-motor armature, from grid G_1, through resistance R_{13} and to the − side of the generator. Pull of this coil increases as the motor-speed and voltage across its terminals increase. The other MM_2 coil is energized by the high-speed switch closing and is from H_1 contact, resistance R_{18}, coil MM_2 to the − line. This causes the MM_2 switch to close and opens contact M in S_2 and the field-switch-coil circuit, but this circuit is still complete through contact S on speed pilot No. 2 contactor.

Speed-pilot Pull-in Coils.—Nos. 1 and 2 speed-pilot contactor pull-in coils are connected in parallel across the generator. The speed-pilot pull-in coils circuits are from the grid G_1 through contact CM_1 to between the two coils, through the coils and to the − on generator. These coils close their contactors shortly after MM_2, first No. 1 and then N. 2. When speed pilot No. 2 closes, it opens contact S and breaks the S_2 and field-switch coils circuit. Contact S_2 opens the circuit through low-resistance grid G_1 in parallel with the generator series-field winding. This builds up the generator voltage and the motor speed increases. When the motor-field switch FS opens, the low resistance R_{37} is disconnected, and the high resistances 38, 39, 40, and 41 remain in parallel and connected in series with the motor shunt field. Generator-field strength is increased and that of the motor decreased and the latter comes up to full speed.

On a one-floor run, MM_2 will close but the speed-pilot switches will not close. The speed-pilot switches gage the distance required by the car to make stops at landings. If neither of the speed-pilot switches closes such as on a one-floor run, slow down is initiated about 3 ft. after leaving the floor to make the run.

Stopping Car from Full Speed.—To stop the car from full speed, the car switch is centered 1.5 to about 1.1 floors from the floor where the stop is to be made. When the car-switch is centered, the circuit is broken through the up-auto pilot and up-pilot pull-in

coils. The up-auto-pilot contact is released and it closes. The up-pilot contact is not released, being held closely by its holding coil. When the up-auto contact closes it completes a circuit for coil MM_3 through the center contact of switch MM_1, top half of resistance R_{10}, coil MM_3, up-auto-pilot and up-pilot contacts and to the − line. Contactor MM_3 closes. When contactor MM_1 closed during starting, coil CM_1 was energized through resistance R_{21} and the automatic leveling switch AL in the car to the − line, but its pull was not sufficient to close contactor CM_1.

When MM_3 closes, its M_3 contact shunts R_{21}, making a circuit for coil CM_1 through contact M_3 to the selector traveling contacts, selector stationary contact U_3, speed-pilot No. 2 contact S_5, speed-pilot No. 1 contact S_1, and to the − line. CM_1 closes its bottom contacts and opens its top contacts. One of the latter is in the high-speed coil circuit. This switch opens and cuts resistance R_9 in series and R_{12} in parallel with the generator shunt-field circuit, weakening it to slow-speed conditions. When the up-auto-pilot contact closed, it also completed a circuit for the speed-pilot pull-out coils through R_{10}, speed-pilot pull-out coils, auto-pilot contact and to the − line. The pull-in coils on the speed-pilot relays are energized and they hold their bottom contacts closed until switch CM_1 closes and opens the circuit through them, when Nos. 1 and 2 speed-pilot bottom contacts open.

Opening the speed-pilot relays, breaks coil circuit CM_1 through U_3 on the selector, but contactor CM_1 is held closed by a circuit through R_{21}. When speed-pilot No. 2 opens, it closes contact S in S_2 and field-switch coils circuit. The field switch closes and puts low resistance R_{37} in parallel with the elevator-motor shunt-field resistance. S_2 also closes and connects grid G_1 in parallel with the generator series field. These two operations bring the motor back to slow speed. When MM_3 closed contact M_2, it made a holding circuit for one-half of coil MM_2 through part of R_{18}, and contact MM_2 remains closed after the high-speed switch opens.

Leveling-switch Coils.—When speed pilot No. 1 opened, a holding circuit was made for coil CM_2 through its contact S', center contact of CM_1 and to the − line. CM_2 closing, makes, through its center contact, a circuit for the three leveling-switch coils in series, through resistance R_{29} and to the − line. These

switches cannot close because they are latched open and are not released until the latch coils are energized when the commutator on the selector completes their circuits.

The latch-coil circuits are made alive up to the selector through center contact CM_2. The latch coil No. 1 is energized by contact S_1 on the selector and C_1 on the commutator closing. The leveling switch No. 1 is released and closes. It opens the circuit through damping winding on the generator field poles, and flux in the polepieces will respond more quickly to changes in the field current. Contacts L_1 open and transfer the generator-field circuit to leveling-switch No. 2 contacts L_2 and puts resistance R_5 in the generator-field circuit. This weakens the generator field and causes further slowing down of the motor.

No. 2 latch-coil circuit is completed by the selector contact S_2 and commutator contact C_2 closing when the car is about 10 in. from the floor. No. 2 leveling contactor is released and closes, transferring the generator-field circuit to contact L_3 on leveling switch No. 3. This puts resistances R_5 and R_6 in series with the generator shunt-field winding, weakening the field to slow down the motor to stopping speed. Contact L_5 on leveling switch No. 2 closed and short-circuited the gate contact through the selector when its gate contacts close. This allows the gate to be opened when the car is within a safe distance of the floor without interfering with normal stopping.

No. 3 leveling switch is released by closing of its latch-coil circuit through contact S_3 on selector and C_3 on the commutator. Closing of No. 3 leveling switch opens the generator-field circuit and causes a dynamic braking action by the motor to bring the car to rest. No. 3 leveling switch also opens the brake-switch-coil circuit through contact L and the brake is applied, its coil being drained through resistances R_{25}, R_{33}, and R_{32} in series. When the brake closes, it opens contacts B_2 and interrupts the direction-switch-coil circuit and these switches open. Opening the direction switches makes all control circuits dead with exception of the safety circuit, which is broken by opening the car gate. All contactors then resume normal dead position ready for the next start.

Selector Contacts.—Selector contacts U_2 and U_1 come into operation on a two-floor and a one-floor run, respectively, to provide a closing circuit for coil CM_1. On a two-floor run speed-pilot No. 1 only closes, so that circuit U_3 of the selector is open

through speed-pilot No. 2 contact S_5. However, circuit U_2 of the selector is closed through contact S_3 on speed-pilot No. 2, contact S_1 of speed pilot No. 1 and to the − line. Consequently, contactor CM_1 closes when U_2 makes on the selector. On a one-floor run the speed pilots do not close and contactor CM_1 closes only after U_1 on the selector makes contact. This circuit is through contact S_4 of speed-pilot No. 1 to the − line.

Should any of the switches in the safety-circuit open when the car is in motion, the reverse-field switch will drop out and the control switches will come to normal-stop position. When the reverse-field switch opens, it connects the generator shunt field across the elevator motor, when the high-speed switch opens. The motor potential is applied in reverse direction to normal on the generator shunt-field coils and causes the field poles to be weakened quickly and to be reversed. This action produces a dynamic braking action by the motor to assist the brake to stop the car in the shortest time with safety. With switch AL open the control becomes a non-automatic and the elevator is controlled entirely by the car switch, except at the terminal landings when the leveling switches operate.

Governor Contacts.—On the governor there are two contacts. One of these is in the safety circuit and the other short-circuits part of resistance R_4 out of the generator shunt-field circuit. If the car starts to overspeed, the governor contact GC will open first and put resistance R_4 in series with the generator shunt-field winding. If this does not bring the elevator under control and its speed continues to increase, the governor contact in the safety circuit will open and the elevator will be stopped as described in the preceding paragraph. Should the control fail to function and the elevator continue to overspeed, the governor would set the car safeties on the guide rails.

CHAPTER XVI

UNIT MULTI-VOLTAGE SIGNAL CONTROL WITH MICRO-LEVELING[1]

Unit Multi-voltage Control.—Several types of automatic signal-control systems, with automatic leveling at landings for elevators, have been developed by the Otis Elevator Company, but the type 11SLU, described in this chapter is typical. Control of elevator-motor speed is by regulating generator voltage, unit multi-voltage control (variable voltages) and leveling is done by the main elevator motor. Power for the elevator is supplied by a motor-generator comprising a three-phase 220-volt squirrel-cage motor, a direct-current compound generator and a compound-wound exciter. The generator has two shunt-field windings, one for normal operation and another for leveling the car into the floors. The motor windings are arranged for starting and idling star connected and delta grouped when the car is in motion, control for which is shown in Fig. 201.

Control Panel.—With this control, Fig. 202, the car is stopped and leveled to floors automatically, either by the car attendant pressing buttons in the car corresponding to floors called by passengers or, in response to buttons pressed at landings by waiting passengers. To start the car, the attendant moves the starting switch *D* to start position Fig. 203. When the hoistway and car doors close, the car starts and accelerates to full speed. After starting, the car switch may be centered and the car will continue in motion until it approaches a floor for which a button has been pressed. It will then slow down and level into the floor, when the car and hoistway doors will open automatically.

Floor Selector.—Floor selectors are required on all automatic-type elevators. On the more modern Otis signal-control elevators the selector performs three important functions: It stops the car at floors for which buttons have been pressed, levels the car at floors, and operates signals necessary for efficient elevator service.

The selector, Fig. 204, may be considered a miniature elevator traveling in a hoistway wherein is conveniently grouped the

[1] Harry F. Cater and William Devaughn assisted in writing this chapter.

operating equipment. A traveling crosshead *C*, representing the elevator, is driven vertically by a steel tape attached to the car and wound on sheaves at the top of the hoistway. Connection between tape-sheave shaft and vertical screw, driving the selector crosshead is made by a chain drive and reduction gears. Pressure on any hall or car button energizes a corresponding

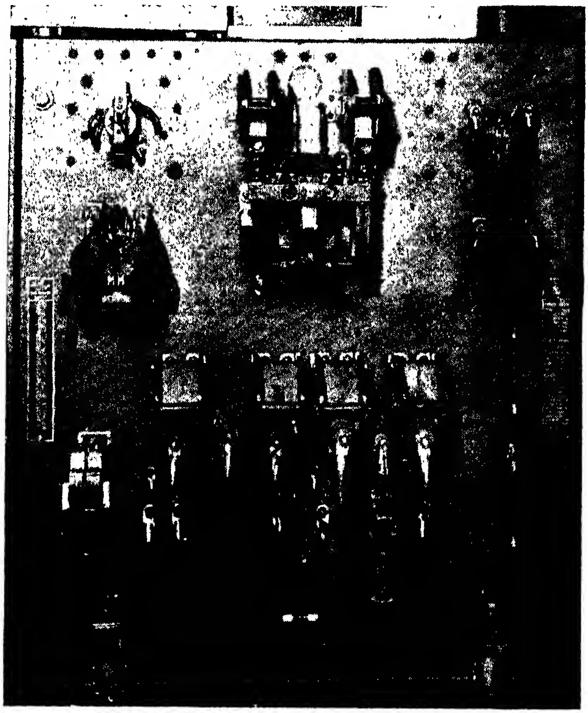


FIG. 201.—Otis Type D-2, alternating-current, three-phase motor-generator starter. Contacts identified on Fig. 205.

stationary contact on the selector. Brushes on the crosshead pick up the signals as the car approaches the desired floors, and stopping operation is then initiated on the controller. The final stop at floor level is controlled by selector cams and contacts.

On the selector are so-called floor boards *B*, Figs. 215 and 217, one for each floor at which stops are to be made. These floor boards are straight bars on which are mounted the up and the down contacts for initiating car stops at floors; contacts for illuminating the hall lanterns, to operate lights in the hall and

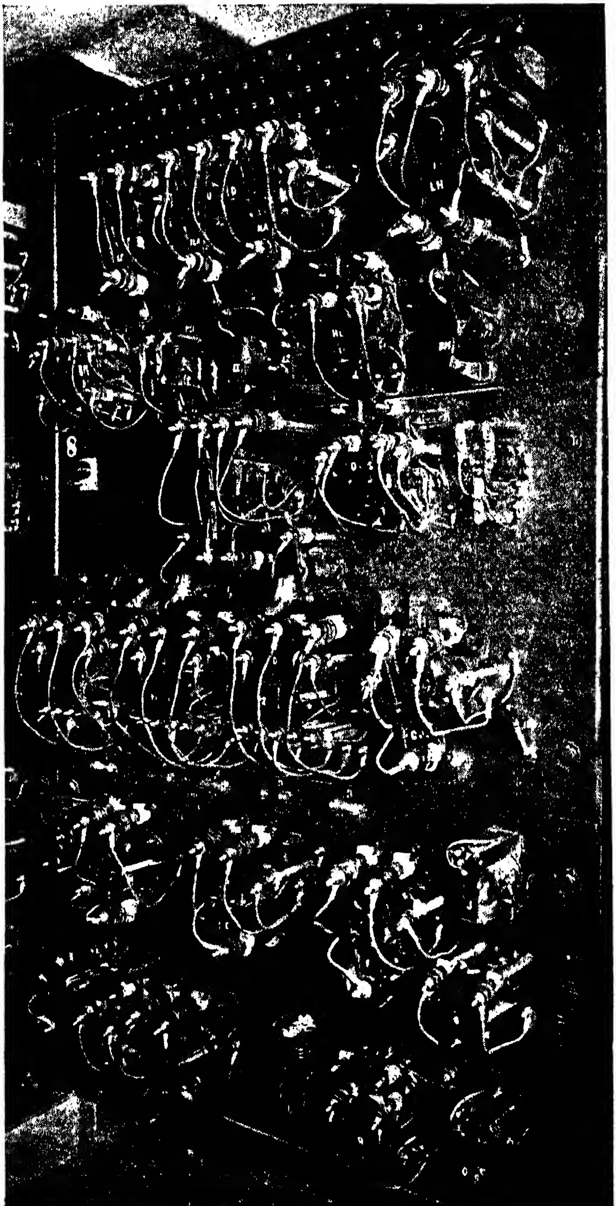


FIG. 202.—Otis Type 11SLU panel for micro-leveling signal control.

the car-position indicator; and other signal units. The floor boards are clamped to three vertical bars so that they may be adjusted vertically.

At the top of the selector, Fig. 204, which is for a Type 11SLU control, are two sets of contacts, Fig. 216. On the right the two rows, with four contacts each are for various circuits in the control system and the slowing down of the elevator to micro-leveling speed. Contact $1U$ controls the micro-leveling-device magnet, $1D$ is in the hall-light relay circuit; $2U$ and $2D$ are in the first high-speed-switch coil circuit; $3U$ and $3D$ are in the generator-field and brake-switch-coil and the auxiliary generator-field and brake-switch-coil circuit; $4U$ and $4D$ are in the car- and hoistway-door operator circuits.

These contacts are closed by weights and opened by movement of the selector crosshead. Two vertical rods R and R_1, Fig. 204, connect to the contacts at their top ends and are connected at their lower ends by a rod and angles, Fig. 213, so that when one rod moves up, the other goes down. On these rods are U-bolts U, one on each rod for each floor at which stops are to be made. As the car approaches a floor at which a stop is to be made, the pawl magnet P, Figs. 204 and 214, is de-energized and the pawls are allowed to drop out and engage a U-bolt corresponding to the floor to be stopped at. As the car slows down, the selector crosshead continues to move and, through the pawl engaged with the U-bolt, moves the vertical rods to open the two rows of contactors at the right, Fig. 216. Thus the car is gradually brought to micro-leveling speed.

The four contacts on the left, Fig. 216, are for micro-leveling, two for high-speed and two for low-speed leveling. The two high-speed leveling contacts H are closed by magnet Mc when the car starts. Contact MU is for up-direction and MD down-direction leveling. These contacts also connect to two vertical square rods V that pass through two roller arms A carried on the selector crosshead, Figs. 204 and 215. When coil M_c is energized, the square rods are rotated to separate the roller arms to clear the leveling cams L. These cams are mounted on a shaft driven from the same gearing as the crosshead screw for control leveling at the floors.

During stopping when $1U$ contact opens, it breaks the solenoid coil M_c circuit, and the leveling contacts are released. If the leveling contacts were free, the mechanism that controls them and

which is attached to solenoid M_c would open the high-speed contacts, close the direction contacts, and then open them. However, when solenoid M_c releases the contacts, assuming the

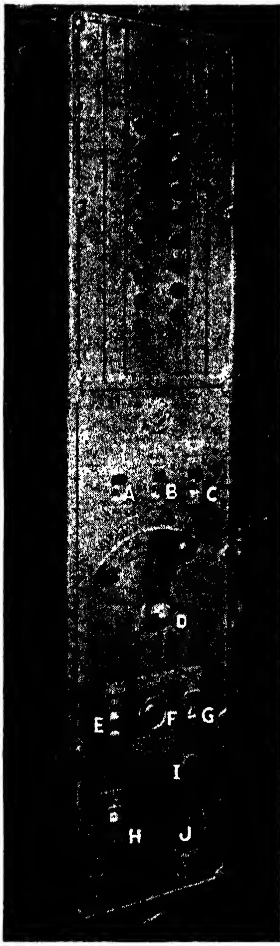


Fig. 203.

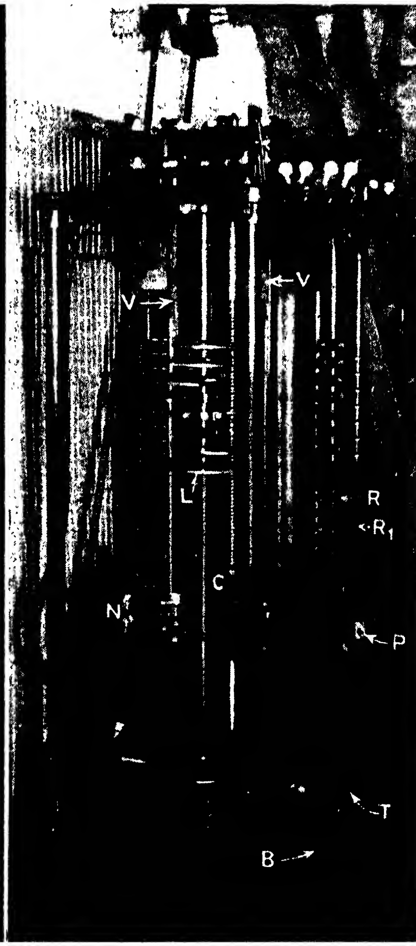


Fig. 204.

Fig. 203.—Car-operator's panel, micro-leveling signal control.

A, nonstop switch; *B*, slow-speed switch; *C*, emergency-stop switch; *D*, operator's-start switch; *E*, micro-control switch; *F*, emergency switch to short circuit door contacts; *G*, car-light switch; *H*, reverse switch; *I*, red light to show when motor generator is running; *J*, key switch for starting motor generator.

Fig. 204.—Floor selector, parts of which are identified in the text.

car in up direction, the roller arms are allowed to close, but the one for up direction leveling is prevented from doing so by a leveling cam.

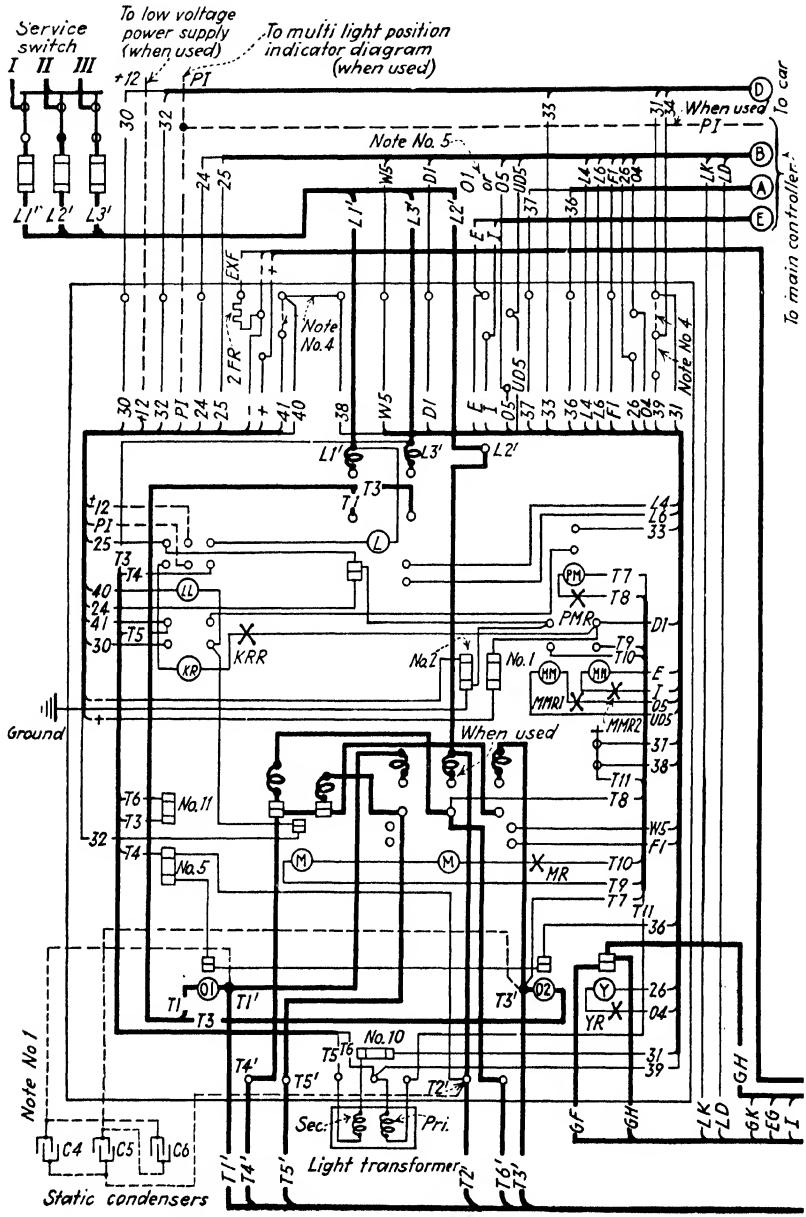


FIG. 205.—Diagram of the control, Fig.

NOTES —

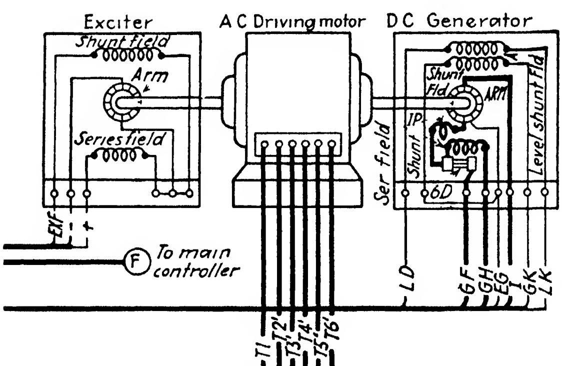
1 — *When static condensers are used connect as shown dotted*

2 — *Before connecting mains to controller, measure the potential between each line and ground and then connect the line of highest potential to line L1.'*

3 — *Markings T1 to T11 inclusive are for convenience of wireman only and are not to be marked on starter*

4 — *For 250 volts or under connect as shown and omit dotted connections between studs 31 and 34 and between 40 and 41 For over 250 volts connect as shown dotted and omit solid connections between studs 34 and 39 and between 38 and 40*

Marking "05" to be used for all types of main controllers except SLU and ALU controllers in which case it becomes 01



NAMES OF SWITCHES

L- Line switch
M- Idling switch
LL- Line switch relay
KR- Running relay
MM Idling switch relay
PM- Idling switch protector relay
01-02- Motor overload relays
Y- Series field switch

201, looking at back of panel.

This cam stops the micro-control mechanism in a position where the up high-speed contact remain closed and the up-direction contact closes. The down-direction leveling contacts open. As the leveling cam continues to rotate it first opens the up high-speed contact and then the up-direction contact as the car stops level with the floor, if the equipment is properly adjusted. When the car stops, the roller arms on the direction leveling contacts just clear their cam, so that if the car moves only a small distance above or below the floor, the slow-speed leveling contact will be closed to bring it back level with the landing.

In this description of the control equipment a motor generator set, the motor of which operates on three-phase power, will be considered. At the top of Fig. 206 is shown a straight-line diagram of a type *D* starting equipment for such a motor. As previously mentioned the motor windings are arranged for star connection during starting and idling periods and for delta grouping when the elevator is operating. Change from one connection to another is made automatically as the elevator is started and stopped.

Starting the Motor Generator.—The switch in the car for motor-generator starting and stopping is a lock type. To start the motor generator, a key is inserted in the lock and turned clockwise, which closes contacts *A* and *B*, contacts *C* and *D* remaining closed. Closing contacts *A* and *B* completes a circuit for the line-switch relay coil *LL*, if the single-pole knife switch on the control panel and the three overload relay contacts, *O*1, *O*2, and *O*3, are closed, as shown in the figure. Overload relays *O*1 and *O*2 are in the motor circuit; and *O*3 in the generator and elevator motor connections; all three being of the lockout type.

The starting circuit is from L_2 line through fuse No. 5, contacts *O*1, *O*2, and *O*3, knife switch *S*, idling-switch relay coil *LL*, contact *Ma*, and to line L_3. Energizing coil *LL*, closes contact *LL* in line-switch coil *L* circuit. Making this coil alive pulls in the two-pole line switch *L*. The motor is now connected star to the line and it starts and comes up to speed. *PM* contact in the start-switch holding circuit is closed by coil *PM*, connected across motor winding T_3-T_6. The motor circuits at one instant are from the L_1 line through switch *L*, motor winding T_1-T_4 to the connection between M_1 switches. Another circuit is from the L_3 line through motor winding T_3-T_6 and left-hand switch

M_1 and joins circuit from line L_1. The two circuits then go through the right-hand M_1 switch, motor winding T_2-T_5 and to the L_2 line. It will be seen that the star connection for the motor windings is formed between switches M_1 and M_1.

As the motor comes up to speed, the exciter builds up its voltage and energizes coil *KR*, contact *LL* having been closed when the line-switch relay *LL* closed. Making coil *KR* alive closes contacts *KR* in the start-switch and light-in-car circuits. Closing KR_1 contact complete a circuit for the lamp in the car and it lights to show that the motor has started and that exciter voltage has built up. KR_2 contact makes the starting-switch holding circuit through contacts *CD* so that the starting key may be removed and the motor-generator continue running.

Elevator-motor Shunt-field Circuit.—A circuit for the elevator-motor shunt field is from D_1 through the field winding with resistance 1*FPR* in parallel, resistance 1*FR*1, contact F_2 shunting resistance 1FR2, relay coil *J* (auxiliary contact *La* having been opened when motor switch *L* closed), to − on the exciter. This excites the elevator motor with a strong field at starting and closes relay contact *J* in the potential-switch circuit. Relay *J* prevents potential switch *C* from closing until the elevator-motor shunt field is excited. If the motor field strength is reduced below a safe value, relay *J* will open and cause potential switch *C* to open, making the control circuits dead and stopping the elevator.

The potential-switch circuit is from + on the exciter through fuse 4, stop switch in the car, safety-plank switch under the car, broken-tape and compensating-rope-sheave switches, top-limit switch L_8, and bottom-limit switch L_6 in hoistway, *La*, governor and *J* contacts, potential-switch coil *C*, auxiliary contact *Ca* on potential switch, CR_1 resistance top-limit hoistway switch L_1, bottom limit hoistway switch L_3, fuse 3, single-pole knife switch on control panel, and to − on the exciter. Potential switch *C* now closes and makes the elevator-motor and generator control panel alive. Auxiliary contact *Ca* opens and connects CR_2 resistance in series with the potential-switch coil. Note: contact *La* was closed by motor switch *L* closing.

Direction-switch Control.—Assume the car at bottom landing ready to start in the up direction. The direction switches are of the mechanical latched-in type and are positioned by a selector contact when the car stops at the terminals landings. As the

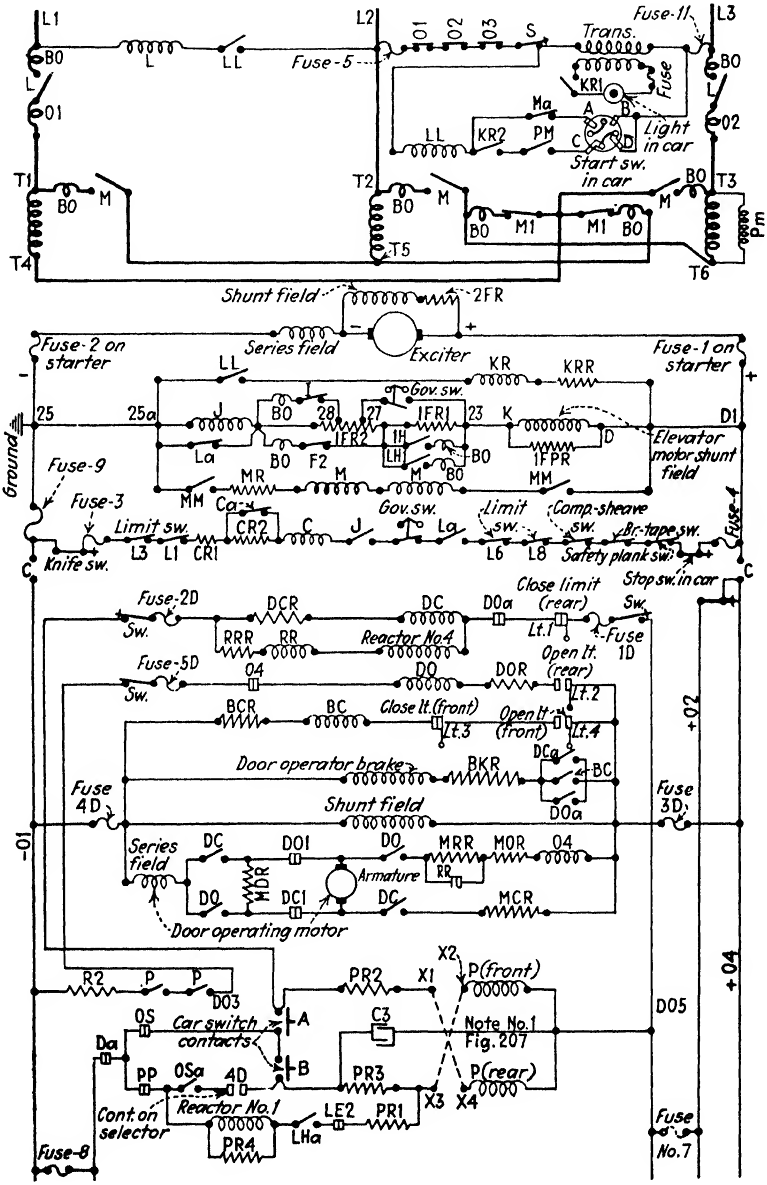


FIG. 206.—Continued on next page.

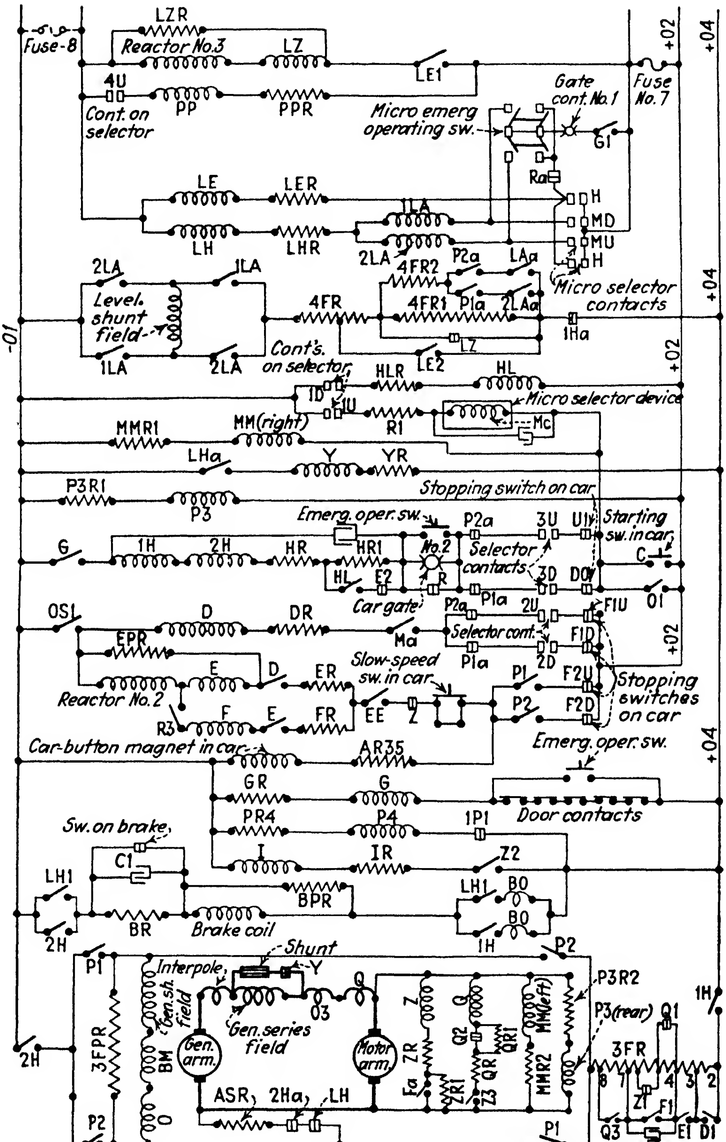


FIG. 206.—Straight-line diagram for Figs. 205 and 210.

car approaches the bottom landing, contact B, Fig. 207, on the selector closes and completes a circuit through up-direction switch coil P_1 and down-direction switch latch coil P_2, contact $1Ha$ and LHa to -01 line. P_1 coil pulls in up-direction switch and it latches closed. P_2 coil unlatches down-direction switch P_2 and it opens.

When P_1 switch closes, it opens contact $P1a$ and makes the coils dead, but up-direction switch remains closed ready for the car to start in up direction. Closing of the up-direction switch closed contacts P_1 and P_1 in the elevator generator-and-motor circuit, at bottom of Fig. 206, but these machines remain dead through contacts $2H$ and $1H$, which are open.

Initial Starting of the Car.—Initial starting of the car in either direction is done by moving the car switch to run position, where it closes contacts in three circuits: One of these is for closing the car and landing doors, a second energizes the closing coil on the stop switch, and the third contact is in the generator-field and brake-switch coil circuit. Circuits for starting are completed by the car and hoistway doors closing.

Door-operator Control.—The door-closing circuit is made by contact A on the car switch. This circuit is from $+02$ line, through fuse $1D$, limit switch Lt_1, door-open switch DOa contact, door-close direction-switch coil DC, DCR resistance, fuse $2D$, car-switch contact A, contacts OS and Da, and fuse 8 to -01 line. Contact DCa closes in the brake-coil circuit, releasing the brake to free the doors so that they may close. Contacts DC and DC close in the door-operator-motor circuit, which starts and closes the car and hoistway doors. The door-operator-motor shunt field is energized all the time by being connected directly to $+04$ and -01 lines. The armature circuit is from $+04$ line through MCR resistance, DC contact, door-operator-motor armature, DO_1 and DC contacts, series-field winding and to -01 line.

When the doors started to close, open limit switches Lt_2 and Lt_4 close. The latter completes a circuit for the brake and cutoff relay coil BC, which when energized close contact BC in the brake circuit. This contact closing allows power to be cut off the motor by opening limit switch Lt_1 and still have the brake released by Lt_3 remaining closed so that the door will drift closed before applying the brake, when Lt_3 opens. About all that the brake does is to hold the doors in the closed or the open position.

After the doors are accelerated, a large part of their retarding is done by dynamic braking the motor. During closing operation,

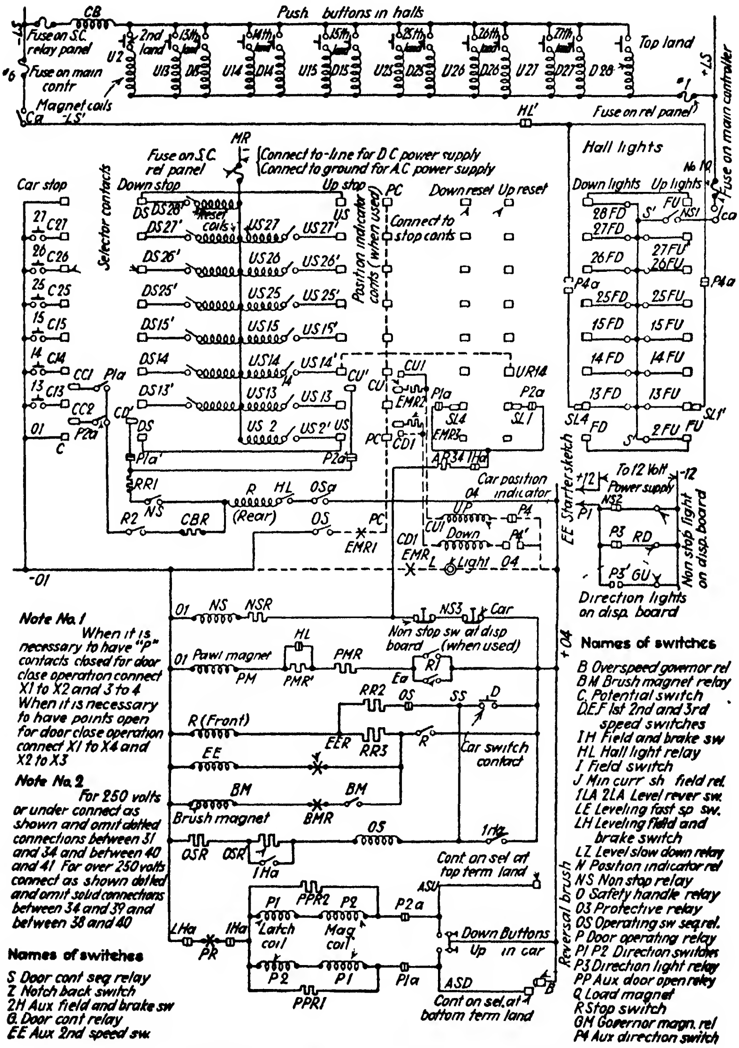


FIG. 207.—Straight-line diagram of stopping and selector circuits.

when direction switch DC opens, it closes contact DC_1 and connects resistance MDR across the motor-armature terminals. The motor then acts as a brake to retard the doors and bring

car approaches the bottom landing, contact B, Fig. 207, on the selector closes and completes a circuit through up-direction switch coil P_1 and down-direction switch latch coil P_2, contact $1Ha$ and LHa to $-O1$ line. P_1 coil pulls in up-direction switch and it latches closed. P_2 coil unlatches down-direction switch P_2 and it opens.

When P_1 switch closes, it opens contact $P1a$ and makes the coils dead, but up-direction switch remains closed ready for the car to start in up direction. Closing of the up-direction switch closed contacts P_1 and P_1 in the elevator generator-and-motor circuit, at bottom of Fig. 206, but these machines remain dead through contacts $2H$ and $1H$, which are open.

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Door-operator Control.—The door-closing circuit is made by contact A on the car switch. This circuit is from $+O2$ line, through fuse $1D$, limit switch Lt_1, door-open switch DOa contact, door-close direction-switch coil DC, DCR resistance, fuse $2D$, car-switch contact A, contacts OS and Da, and fuse 8 to $-O1$ line. Contact DCa closes in the brake-coil circuit, releasing the brake to free the doors so that they may close. Contacts DC and DC close in the door-operator-motor circuit, which starts and closes the car and hoistway doors. The door-operator-motor shunt field is energized all the time by being connected directly to $+O4$ and $-O1$ lines. The armature circuit is from $+O4$ line through MCR resistance, DC contact, door-operator-motor armature, DO_1 and DC contacts, series-field winding and to $-O1$ line.

When the doors started to close, open limit switches Lt_2 and Lt_4 close. The latter completes a circuit for the brake and cutoff relay coil BC, which when energized close contact BC in the brake circuit. This contact closing allows power to be cut off the motor by opening limit switch Lt_1 and still have the brake released by Lt_3 remaining closed so that the door will drift closed before applying the brake, when Lt_3 opens. About all that the brake does is to hold the doors in the closed or the open position.

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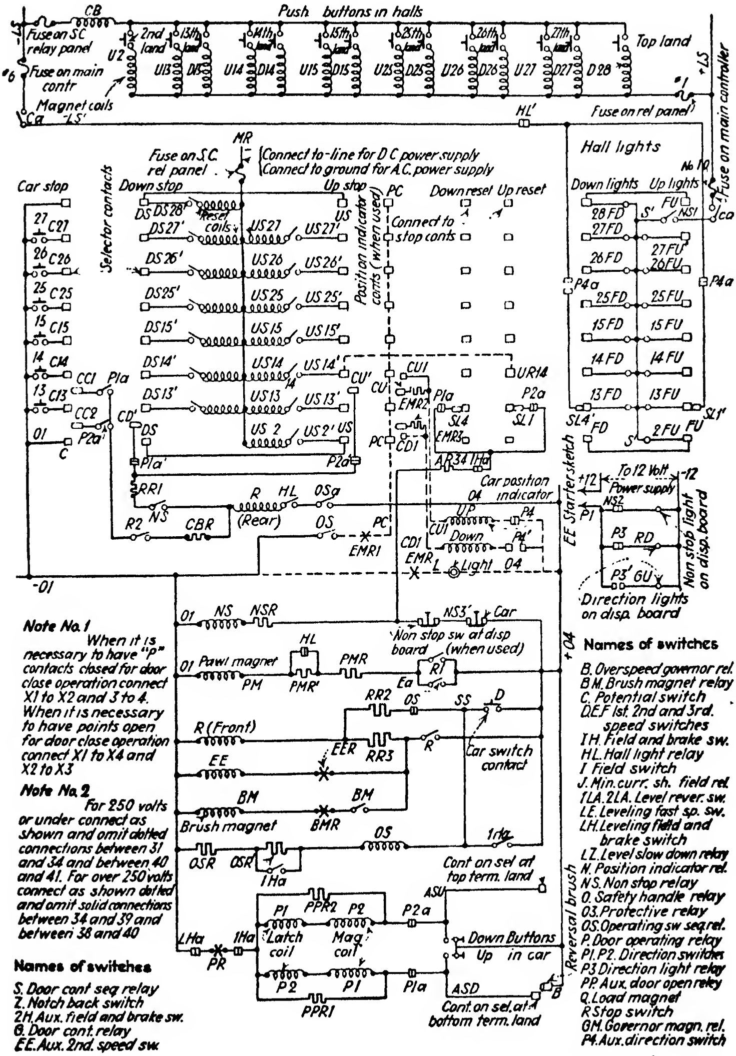


FIG. 207.—Straight-line diagram of stopping and selector circuits.

when direction switch *DC* opens, it closes contact DC_1 and connects resistance *MDR* across the motor-armature terminals. The motor then acts as a brake to retard the doors and bring

car approaches the bottom landing, contact B, Fig. 207, on the selector closes and completes a circuit through up-direction switch coil P_1 and down-direction switch latch coil P_2, contact $1Ha$ and LHa to -01 line. P_1 coil pulls in up-direction switch and it latches closed. P_2 coil unlatches down-direction switch P_2 and it opens.

When P_1 switch closes, it opens contact $P1a$ and makes the coils dead, but up-direction switch remains closed ready for the car to start in up direction. Closing of the up-direction switch closed contacts P_1 and P_1 in the elevator generator-and-motor circuit, at bottom of Fig. 206, but these machines remain dead through contacts $2H$ and $1H$, which are open.

Initial Starting of the Car.—Initial starting of the car in either direction is done by moving the car switch to run position, where it closes contacts in three circuits: One of these is for closing the car and landing doors, a second energizes the closing coil on the stop switch, and the third contact is in the generator-field and brake-switch coil circuit. Circuits for starting are completed by the car and hoistway doors closing.

Door-operator Control.—The door-closing circuit is made by contact A on the car switch. This circuit is from $+02$ line, through fuse $1D$, limit switch Lt_1, door-open switch DOa contact, door-close direction-switch coil DC, DCR resistance, fuse $2D$, car-switch contact A, contacts OS and Da, and fuse 8 to -01 line. Contact DCa closes in the brake-coil circuit, releasing the brake to free the doors so that they may close. Contacts DC and DC close in the door-operator-motor circuit, which starts and closes the car and hoistway doors. The door-operator-motor shunt field is energized all the time by being connected directly to $+04$ and -01 lines. The armature circuit is from $+04$ line through MCR resistance, DC contact, door-operator-motor armature, DO_1 and DC contacts, series-field winding and to -01 line.

When the doors started to close, open limit switches Lt_2 and Lt_4 close. The latter completes a circuit for the brake and cutoff relay coil BC, which when energized close contact BC in the brake circuit. This contact closing allows power to be cut off the motor by opening limit switch Lt_1 and still have the brake released by Lt_3 remaining closed so that the door will drift closed before applying the brake, when Lt_3 opens. About all that the brake does is to hold the doors in the closed or the open position.

After the doors are accelerated, a large part of their retarding is done by dynamic braking the motor. During closing operation,

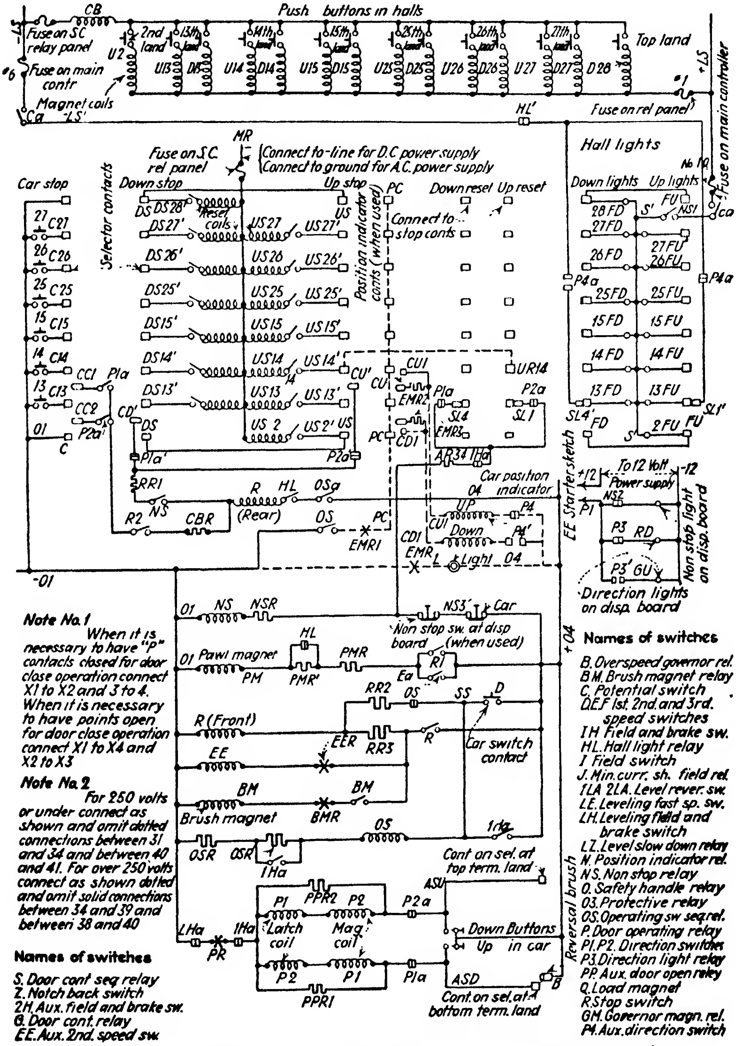


FIG. 207.—Straight-line diagram of stopping and selector circuits.

when direction switch DC opens, it closes contact DC_1 and connects resistance MDR across the motor-armature terminals. The motor then acts as a brake to retard the doors and bring

them nearly to rest in closed position when the brake shoes are applied.

On the car switch there are three positions, two in the run direction and one in the door-open position. Moving the car switch to the first run position would close contact *A* only. This will close the doors, but the car will not start. If the car switch is centered, the doors will remain closed. Then to open the doors, the car switch must be moved to door-open position. This closes contact *B* and makes a circuit for the front coil of *P* relay through resistance PR_3, contacts *B*, *OS* and *D*a to the −01 line. Relay contacts *P* and *P* close and complete a circuit for open direction-switch coil *DO*.

The opening operation is practically the same as the closing. When the doors are closing the rear coil of relay *P* is energized through the car switch contact *A* and opens *P* relay contacts. Several types of door operator and controls may be used with this elevator control besides the one shown. Frequently the operator opens the doors only, and puts springs in tension to close them when the brake is released.

How the Control Functions during Starting.—When contact *A* closed to energize the door operator, contact *D*, Fig. 207, closed a circuit for stop-switch *R* front coil, from +04 line, *OS* contact, RR_2 resistance, front *R* coil to −01 line. This switch closes several contacts, one of which is *R* to complete a holding circuit for its front coil, locking the switch closed so the car switch may be centered and the control circuits remain alive. Closing the car switch contact *D*, also made a circuit for the operating-switch sequence relay *OS*, but this relay cannot close until contact 1*Ha* on the field and brake switch closes. When the stop switch *R* functioned, it also closed contact R_1 and completed the circuit for the pawl magnet, which when energized releases contacts 1*U* to 4*U* and 1*D* to 4*D* on top of the selector and they close, Fig. 216. All circuits for the control are included in Fig. 206 (on two pages) and in Fig. 207. In the following description of the circuits it will be necessary to refer quite frequently from one diagram to another.

When the hoistway doors close they complete a circuit for the door-contact relay coil *G*, Fig. 206, from +04 line through door contacts, door contact-relay coil *G*, resistance *GR* to −01 line. The relay closes contact *G* in field- and brake-switch coil 1*H* circuit, and auxiliary field- and brake-switch coil 2*H* circuit. This

circuit is from +O2 line contact *C* on the car switch, contact *U*1 on stopping switch on top of car, selector switch contact 3*U* (closed when the pawl magnet was energized), down-direction

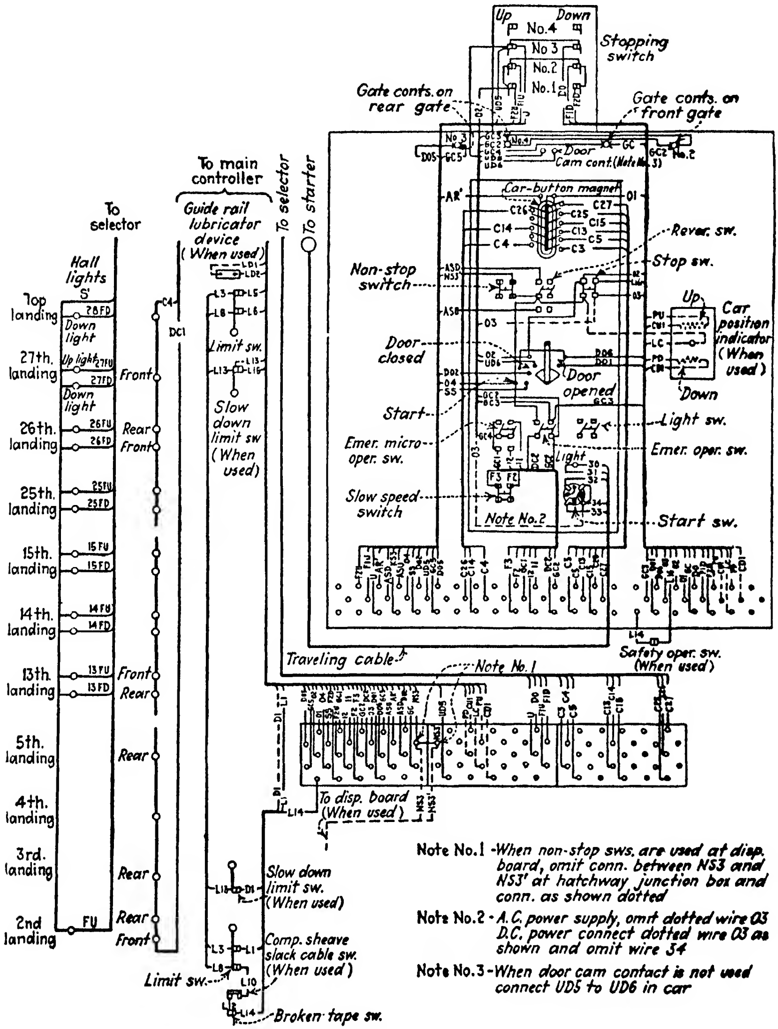


FIG. 208.—Car switch-panel and limit-switch circuits.

switch contact *P*2*a*, car-gate contact No. 2, contacts E_2 and *HL* (contact *HL* was closed when hall-light relay coil *HL* was energized by contact 1*D* closing on the selector), resistance *HR*,

coils $2H$ and $1H$, and contact G to the $-O1$ line. Switches $1H$ and $2H$ close the brake-coil and the generator-field circuits. The brake is released and excitation applied to the generator.

The brake circuit is from $+O4$ line, through contact $1H$, the brake coil, contact on brake, $2H$ contact and to the $-O1$ line. The brake is released and its contact opens, putting resistance BR in series with the brake coil. The generator shunt-field circuit is from $+O4$ line through contact $1H$, the field resistance (except that part short-circuited by contacts $Q1$ and $Z1$), contact $P1$, safety-handle relay coil O, selector-brush magnet relay coil BM, the generator shunt-field winding, contacts $P1$ and $2H$ to the $-O1$ line.

The generator field is made alive with low excitation and the elevator motor starts at slow speed. When relay $2H$ functioned, t opened contact $2Ha$ to isolate the motor and generator armatures from the excitation circuit. Contact Y is closed to connect the shunt across the generator series field winding. The generator has a weak field and the motor a strong shunt field, resistance $1FR2$ being short-circuited by contact F_2 and $1FR1$ by contact $1H$, the latter closed when $1H$ relay was energized. These conditions cause the motor to operate at slow speed.

When relay coil O in series with the generator shunt field is made alive it closes contact $O1$, in parallel with the car-starting switch C. This contact maintains a circuit through relay coils $1H$ and $2H$ after the starting switch is centered.

When the brush magnet coil BM is energized it closes contact BM in the selector brush-magnet-coil circuit, Fig. 207. This coil advances the selector brushes in the direction that the crosshead is traveling.

When the car-starting switch was closed, it also completed a circuit through the right-hand coil MM of the idling-switch relay, on the motor-generator start panel, through resistance $MMR1$ to $-O1$ line, and this relay closes its two contacts. This completes the circuit for the two coils on idling switch M, which are connected across the exciter from $+$ to $-$ lines. The M switch throws over and changes the motor connections from star to delta, by opening the two $M1$ and closing the three M contacts.

The left-hand coil of the idling-switch relay MM is connected across the elevator-motor terminals. This coil holds the relay closed after the right-hand coil has been de-energized during stopping, until the elevator almost comes to rest. When switch

M functions it closes the auxiliary contact *Ma* in the first-speed-relay coil *D* circuit. This contact prevents the elevator control

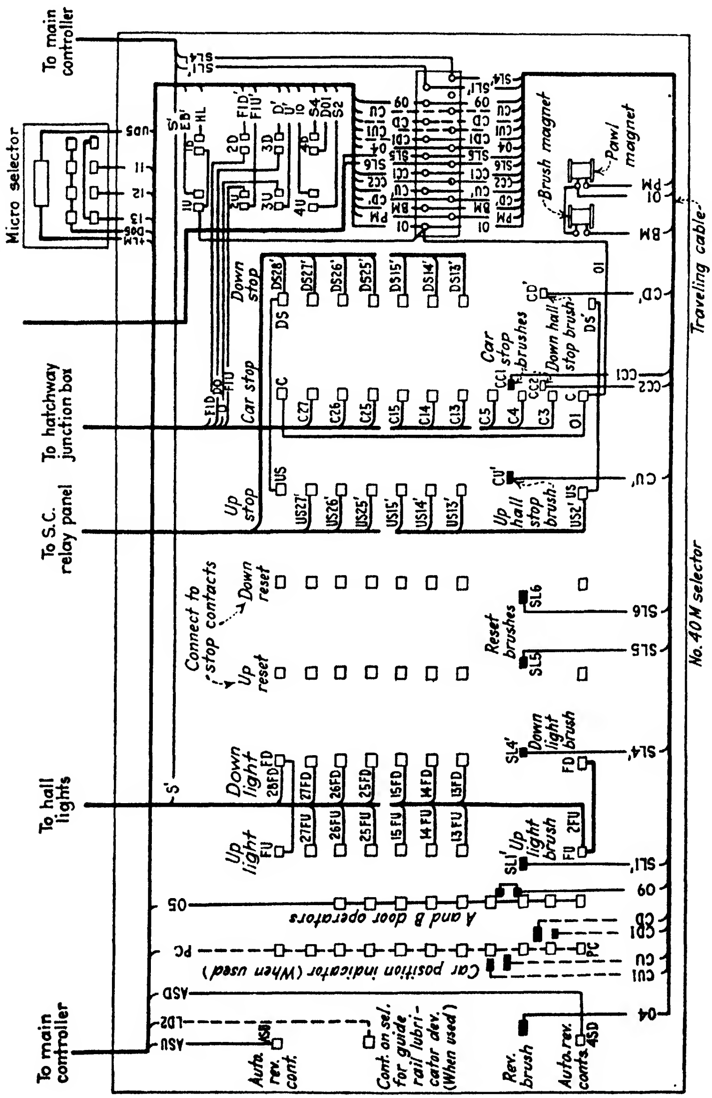


FIG. 209.—Diagram of selector connections.

from switching to high speed until the driving motor on the generator has been conected delta.

Coil *EE* of auxiliary second-speed switch is energized through the same *R* contact as is the pawl magnet and closes its contact *EE*

in the 2nd, and 3rd speed circuits E and F, respectively. When relay $1H$ closed, it made contact $1Ha$ to short-circuit resistance OSR^1 and energizeed coil OS of operating sequence relay strong enough for it to close its contacts, one of which, $OS1$, is in the 1st-, 2nd-, and 3rd-speed circuits D, E, and F, Fig. 206.

The 1st-speed circuit is through coil D, from $+O2$ line through $F1U$ contact on the stopping switch on the car, selector contact $2U$, $P2a$ contact on the direction switch, Ma contact on motor-generator switch M, resistance DR, coil D, relay contact $OS1$ and to the $-O1$ line. Relay D closes two contacts. One of them, $D1$, closes across a section of generator shunt-field resistance, raises the generator voltage, causing the elevator motor to increase in speed.

The other contact on D relay completes the circuit for the second-speed relay coil E. This coil is in series with an iron-core reactor coil, to time the closing of D. When E closes it pulls in contact E_1 to cut out a section of resistance in the generator-field circuit. It also closes contact E to complete the circuit for third-speed relay coil F and opens contact E_2 across HR_1 resistance and puts it in series with coils $1H$ and $2H$.

Closing of relay F is timed by the same reactor as E. When relay F closes, it makes contact F_1 across a section of generator shunt-field resistance, now partly short-circuited by contacts Q_1 and Z_1 and opens contact F_2 in parallel with the motor shunt-field resistance $1FR_2$. The motor again increases in speed due mostly to connecting resistance $1FR2$ in series with the motor field.

When relay F pulled in, it closed contact Fa across resistance ZR_1 in series with relay coil Z. This relay functions and opens a contact across a section of generator-field resistance now short-circuited by contact F_1. Relay Z also closes a contact, Z_2, in series with field-switch coil I and another, Z_3, in series with relay coil Q across the motor armature. Field switch I functions and opens a contact across a section of motor field resistance $1FR2$.

Closing Z_3 contact in series with Q relay coil causes this relay to function and open a contact Q_2 in series with its coil and connects resistance QR_1 into circuit. Contact Q_1 opens across a section of resistance in the generator shunt field already short-circuited by contact F_1. Contact Q_3 closes, short-circuits the last section of resistance out of the generator shunt field, and the motor comes up to full speed.

When the car switch was closed it also completed a circuit through coil *Mc* on the micro-selector device that controls the position of the leveling contacts while the car is in normal operation. Coil *Mc* closes the high-speed micro-selector contacts *H* and energizes coil *LE* of the fast-speed micro-leveling switch. This switch closes contact LE_2 across the resistance in series with the generators leveling shunt-field winding. This field-winding circuit is still open through direction contacts 1*LA* and 2*LA* and auxiliary 1*Ha* contact, the latter opening when 1*H* switch closed. Switch *LE* also closes a contact LE_1 in series with leveling slow-down relay coil *LZ*. Making this coil alive opens contact *LZ* across a section of the generator leveling shunt-field resistance. This section is short-circuited by contact LE_2 and does not come into effect until the car is leveling into the floors.

Car-passenger Floor Stops.—Floor stops for passengers in the car are made by pushing buttons located above the starting switch, Fig. 203. The buttons are numbered according to floors at which stops can be made. When they are pressed they are held closed by one large magnet in back of them. The circuit for this magnet when the car is in up direction is from the +02 line, stopping-switch contact *F2U* on top of the car, P_1 contact on up-direction switch, resistance AR_{35}, car-button-magnet coil and to the −01 line, Fig, 206. This magnet is energized all the time except at the terminal landings.

As the car approaches the top landing, contact *F2U* opens the circuit through the car-button-magnet coil and the buttons are released. Near the terminal, the down-direction switch coil is energized and that switch closes and the up-direction switch opens. When the down-direction switch closes, it also closes contact P_2 in the car-button-magnet circuit through stopping-switch contact *F2D*. The car-button magnet is then energized to hold the buttons closed when they are pressed for down-direction stops.

As shown in Fig. 207, when the car-stop buttons are closed, they completed a circuit to a contact on the selector. For example, if button 14 is pressed, it is held closed by the car stop-button magnet and completes a circuit to C_{14} contact on the selector. On the selector carriage are two brushes CC_1 for up-direction stops and CC_2 for down-direction stops. Brush CC_1 is set a little higher on the brush carriage than is CC_2, so that in up travel CC_1 brush is in advance of CC_2 and in down direction

CC_2 will be ahead of CC_1. This is necessary because up stops must be picked up when the car is below floors and down stops when the car is above floors.

Auxiliary contact $P1a$ on the up-direction switch P_1 is closed to complete the stopping circuit, Fig. 207. Contact $P2a$ on the down-direction switch is open and prevents down-direction brush CC_2 from making a circuit for up-direction signals. In down direction, $P1a$ contact is open, $P2a$ closed, and CC_2 contact makes the stopping circuit.

Closing No. 14 car-stop button when the car is going up, brush CC_1 picks up stationary contact C_{14} on the floor selector and completes a circuit from the +04 line, through OSa and HL contacts, rear coil on R switch, CBR resistance, contacts R_2 and $P1a$, selector contact C_{14}, stop button 14, and to the −01 line.

Switch R is a quick-release type with a light-steel armature held to the contactor arm by two spiral springs. When the switch is closed by the front coil the armature is pulled away from the contactor arm about $\frac{1}{4}$ in. When the rear coil of R is energized, which is connected to oppose the front coil and for greater magnetizing power than it is, the armature is released and the springs snap it back against the contactor arm, which drops quickly to the open position.

When R opens, it breaks the stopping circuit by opening contact R_2 and de-energizes the rear coil or switch R. Contact R in series with the front coil of switch R is opened and de-energizes the front coil of this switch so that it cannot close again. Switch R cannot now close, even if the car switch is held in the start position, because contact OS in series with this switch is open as long as switch OS is closed. When contact R opened, it also broke the circuit through coil EE of the auxiliary second-speed switch and the circuit through the floor-selector brush magnet coil BM.

Energizing the brush magnet moved the up-direction brushes a short distance in the up direction and the down-direction brushes in a down direction. De-energizing the brush magnet allows the up-direction brush to move downward and the down brushes upward. This action delays the brushes on the stopping contact to hold the connections closed until switch R has opened the circuit and relieves the selector contacts of this service.

When R opened, it broke contact R_3 in series with high-speed switch coil F. This switch opens its contact F_1 and connects

the section of resistance between 4 and 7 in series with the generator shunt field. This reduces the generator voltage, causing the elevator motor to slow down. At the same time F_2 contact, in parallel with motor field resistance $1FR2$, closes and short-circuits this resistance out of the motor field. This increases the motor-field strength and causes it to slow down, as did connecting resistance in series with the generator shunt field.

As previously mentioned, coil *EE* was made dead when switch *R* opened and this in turn opened contact *EE* in series with high-speed switch coils *E* and *F*. Switch *F* opened immediately when *R* opened, but *E* is delayed in opening, having an inductive circuit closed through reactor No. 2 and resistance *EPR*, until after *F* has dropped out. When *E* opens, it puts resistance section between 3 and 4 in series with the generator shunt field, causing a further slowing down of the elevator motor. Contact *Ea*, in series with the selector pawl magnet coil, is also opened, contact R_1 having been opened previously when contactor *R* opened.

When the pawl magnet is made dead, it releases its pawls, which engage a U-bolt on the rods that operate the stopping switches on top of the selector. First, contact 2*U* opens and breaks the circuit through high-speed switch *D* coil. When *D* opens, it connects resistance section between 2 and 3 in series with the generator shunt field, and the motor slows down. Voltage across the motor terminals has been reduced to where contact Q_3 opens and cuts resistance section, between 7 and 8, in series with the generator shunt field. The motor is slowed down now to normal slow speed. Next, 1*U* opens and de-energizes coil *Mc* of the micro-selector device. Up-direction micro-leveling selector contact *MU* then closes the circuit through up-direction leveling-switch coil 2*LA* and leveling-field and brake switch coil *LH*. Contacts 2*LA* close and connect the generator leveling field winding in circuit, but this circuit is still open through contact 1*Ha*. *LH* coil closes contacts LH_1 in parallel with contacts 2*H* and 1*H*, in the brake-coil circuit, so that the latter two may open and the brake coil remain energized.

An instant after 1*U* selector-switch contact opens, 3*U* breaks and de-energizes coils 2*H* and 1*H*. These switches drop out and open contacts 1*H* and 2*H* in the brake and generator-field circuits, and close contact 1*Ha* in the leveling field circuit. This kills the running shunt-field winding and makes alive the leveling shunt-field winding in the generator.

When *LH* switch pulled in, it closed contact LH_1 across resistance $1FR_1$ in the elevator-motor field circuit to keep this resistance cut out of the circuit when switch 1*H* opened. Contact *LHa* also closes and completes a circuit for *Y* coil from the +04 line through resistance *YR*, coil *Y*, contact *LHa* to −01 line. Coil *Y*, when made alive, opens contact *Y* and puts the generator series-field winding in circuit for leveling. Contact 1*Ha* opens in *OS* coil circuit and this switch drops out its several contacts.

Magnet coils *O* and *BM* were de-energized when the running shunt-field winding on the generator was opened. Contact O_1 in parallel with the car-switch contact opens and makes right-coil *MM* of idling-switch relay dead. This relay is held closed, however, by coil *MM* connected across the elevator motor terminals, until the motor almost comes to rest. Making *BM* coil dead opens contact *BM* in the pawl magnet circuit, which has previously been killed by contact *R* opening.

Micro-leveling Operations.—As previously described, when the coil of the micro-selector device is de-energized, control of opening and closing of the micro-contacts is taken by a cam. This cam at first prevents the high-speed leveling contacts from opening. As the cam continues to turn, with the motion of the car, contacts *H* are allowed to open and break *LE* coil circuit. Making this coil dead opens contact LE_2. Opening this contact groups in parallel resistances 4*FR*1 and 4*FR*2 and these two in series with resistance 4*FR*, in series with the leveling shunt-field winding. Weakening the generator field causes the motor to slow down.

When *LE* opened, it also broke the circuit for leveling fast-speed switch coil *LZ*. Opening of this switch is delayed by coil *LZ* being connected in the inductive circuit formed by reactor No. 3 and resistance *LZR*. When *LZ* coil releases its armature, it closes contact *LZ* to shunt resistance 4*FR*1 and 4*FR*2 out of the leveling field-winding circuit. At about the same time the micro-leveling cam releases contact *MU* and breaks the circuit through 2*LA* and *LH* coils. These contactors drop out and open the brake-coil circuit and the brake is applied to stop the car level with the floor. LH_1 contact opens and cuts resistance 1*FR*1 in series with the elevator-motor field winding. Contacts 2*LA* open to disconnect the generator leveling shunt-field winding and contact 2*LAa*, in series with resistance 4*FR*2, breaks the circuit through this resistance.

When the car stops level with the floor, the rolls in the two arms *A* that control opening and closing of the micro-leveling contacts just clear their leveling cam, Fig. 215. If for any reason the car stopped 0.5 in. or more above the floor, the down slow-speed leveling contact *MD* would have been closed by the leveling cam. This would energize the brake and the slow-speed leveling circuits to bring the car back level with the floor. As the car comes to rest at the floor, all contactors are in normal running position.

Door-opening Operation.—When the car is leveling into the floor, car and hoistway doors are being operated so that they will be open about the time that the car is level with the floor. When 1st-speed magnet *D* opened, it closed contact *Da* in the door-operator circuit. Contact *PP* in the door-opening circuit closed when selector contact *4U* opened the circuit through auxiliary door-open relay coil *PP*. Contact *LHa* closed when the micro-leveling circuits are energized and contact LE_2 closes when the high-speed micro-leveling circuit is de-energized.

When contact LE_2 closes, it completes a circuit for the front coil on the door-operating relay *P* from +02 through front coil *P*, resistance PR_1, contacts LE_2 and *LHa*, reactor No. 1 and PR_4 resistance in parallel, contacts *PP* and *Da*, and to the −01 line. Contacts *P* and *P* close and complete the circuit for the door-opening switch *DO*. This circuit is from the +04 line through the limit switch Lt_2 (closed when the doors closed), resistance *DOR*, coil *DO*, stall-relay contact 04, contacts *P* and *P* to the −01 line. Coil *DO* closes direction contacts *DO* and *DO* and opens contact DO_1. This energizes the motor to open the doors, operation being much the same as when they closed. When the doors have opened, limit switch Lt_2 opens, stops the motor, and the brake is applied to hold them in the open position.

Micro-emergency Leveling.—The micro-emergency-leveling switch may be used to bring the car to the floor in case it cannot be operated from the start switch. With the hoistway doors and car gate closed, the door-contact relay functions and closes contact G_1. Car gate No. 1 contact also is closed. These make the micro-emergency switch alive. Contact *Ra* is also closed because contactor *R* is open. If the micro-emergency switch is closed to the down position, its right-hand pole makes the high-speed leveling switch coil *LE* alive. Its left-hand pole energizes the up-direction coil *2LA* and the car starts. Throwing the

micro-emergency-operating switch to the up position will energize the down-direction leveling switches and the car will move downward. When operated from the micro-emergency switch, the car runs at fast micro-leveling speed, which is about 50 ft. per min.

Stops Made From Hall-buttons.—Stops made from hall buttons being pressed by waiting passengers involve a somewhat more complicated selector and relay arrangement than do those made from car buttons. In the car one set of buttons serves for both up and down directions and one magnet coil serves to hold the floor buttons in the closed position. At each landing, with exception of the terminals, two call buttons are provided, one for up and the other for down direction. When the buttons are pressed the calls are registered by relays, one relay for each button. On these relays are two coils. One of the coils is energized when its hall button is pressed and closes a contact. This contact makes a stopping circuit to a stationary contact, on the selector, to be picked up by a brush on the selector carriage. The second coil on the relay is energized by another contact on the selector, to reset the relay when the floor call has been made. The hall push-button relays are assembled on a panel, as shown in Fig. 211.

Provisions are made to bypass floor call to a following car. This is done by relay *NS*, the coil of which is in series with the non-stop buttons, one in the car and the other on the dispatcher's board. These two buttons are normally closed and make a circuit for *NS* relay coil from +04 through *NSR* resistance, coil *NS* to −01 line. This relay closes a contact *NS* in the common lead to down-stop brush *CD'* and up-stop brush *CU'* on the selector carriage.

Contact *NS* is normally closed and the selector contact circuit is complete for the cars to pick up floor calls. If the car were full and the operator did not wish to pick up any more passengers, by pressing the non-stop button, *NS* relay contact will open to prevent the floor calls being picked up. They will be bypassed to the following car.

P1a' and *P2a'* contacts in series with *CD'* and *CU'* selector brushes, respectively, allow the car to be stopped for calls corresponding to the direction in which it is going. *P1a'* contact is open when P_1 up-direction switch closes. This breaks the circuit to down-direction-call selector brush *CD'* and it cannot

stop the car when going up. In down direction $P1a'$ is closed and $P2a'$ open.

The reset brushes SL_4 and SL_1 on the selector are also in series with $P1a'$ and $P2a'$ contacts on the direction switches, so that only up-direction calls will be reset when the car is in up motion, and down-direction calls when the car is in down motion. The $1Ha$ contact in series with both selector brushes SL_4 and SL_1 is open as long as switch $1H$ is closed, when the car is operating above micro-leveling speed. Therefore, unless the car stops at a floor, the floor-call signals will not be reset.

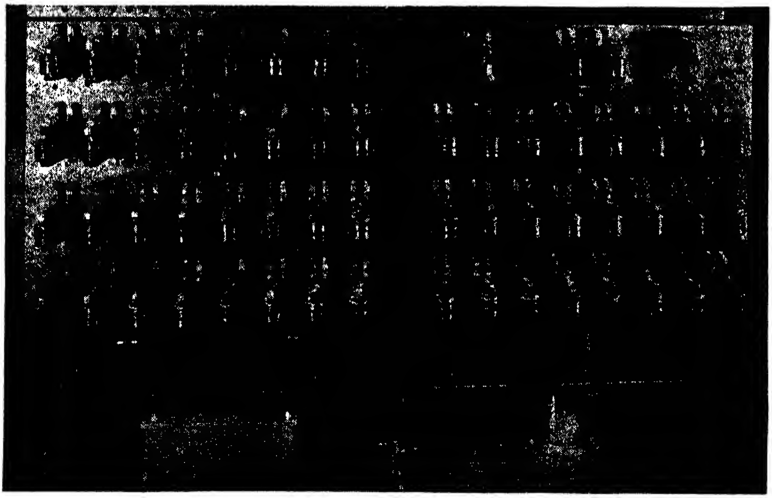


Fig. 211.—Floor-call relay panel.

The hall lights, to indicate to waiting passengers when and in what direction a car is approaching, are also controlled from the selector. Stationary *FU* contacts on the selector are for up-direction lights and *FD* stationary contacts are for down-direction lights.

When the car is going up, the selector brush SL_1' is connected into the circuit by the P_4 relay contact, $P4a$ being closed when the relay is made dead by the contact $1P_1$ being open when up-direction switch P_1 is closed. In down direction, P_1 direction switch is open and $1P_1$ contact in series with P_4 relay coil is closed. This makes coil P_4 alive and contact $P4a$, in series with selector brush SL_4', closes so that the down-direction lamps will light. Contact $P4a$ in series with selector brush SL_1' is

open; therefore the up-direction lamps cannot light when the car is going down.

The current to light the hall lamps is controlled by relay *HL*, the coil of which is in series with contact $1D$ on top of the selector. When the pawl magnet releases the contacts on top of the selector, when the car starts, $1D$ closes and completes the circuit for relay coil *HL* from the +02 to the −01 line. Contact HL_1 opens and breaks the power circuit to the hall lamps. The *Ca* contacts in the hall-light circuit are on the potential switch and close when this switch pulls in, so that as long as this switch is closed, power is on the hall-light circuit.

Contact NS_1 in series with the $+LS$ line, leading to the common connection for the hall lights, is on the non-stop relay and is normally closed. If the non-stop switch is open in the car or on the dispatcher's board, for the car to run non-stop, NS_1 will open and cut power off the hall lamps. This will prevent their lighting even if the opposite side of the lamps were grounded.

Non-stop relay has a third contact NS_2, in series with a light on the dispatcher's board. This contact closes when *NS* relay is dropped out by opening of a non-stop switch and lights the non-stop lamp on the dispatcher's board. The chief purpose of this light is to show the dispatcher when the operator is running non-stop.

Dispatchers Board.—Lights on the dispatcher's board show the direction in which the car is going. These lights are controlled by relay P_3. This relay has two coils. One of them, the front coil, is connected directly from the +02 to the −01 lines and is energized all the time that the stop switch in the car is closed. The other P_3 relay coil is connected across the elevator motor, so that when the motor reverses, the direction of current flow in this coil is changed. The two coils of relay P_3 are on the same core; consequently, with the motor running in one direction the coils assist each other. When the motor runs in the opposite direction, the two coils on P_3 have opposite polarity.

Front coil P_3 cannot close the relay alone; therefore, as long as the rear coil opposes it—such as when the elevator is in the down direction—the relay will not pull in, even when the elevator is stopped. Under this condition down-contact P_3 will remain closed and up-contact P_3' will stay open. When the car starts up, the polarity of the motor reverses, the two P_3 relay coils have the same polarity, and the relay open. When the relay

closes, its front coil can hold it closed, keeping down contacts P_3 open and up contact P_3' closed. Thus contacts P_3 and P_3' are controlled automatically with the direction of the motor.

Car-position Indicator.—On the selector are shown contacts for the car-position indicator, which shows car passengers the number of the floor that the car is approaching. There are a single row of stationary contacts on the selector for this device and two groups of two brushes each on the carriage to operate the position indicator. The up- and the down-direction circuits are controlled by relay P_4. In the up direction, this relay is deenergized and contact P_4, in series with up coil of the indicator, is closed. On down direction, relay P_4 is energized, opening

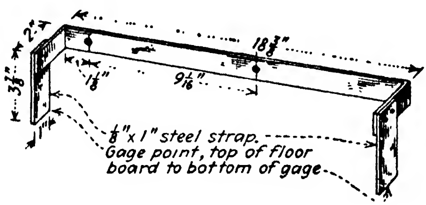


Fig. 212.—Gage for setting floor boards on selector.

contact P_4 in the up-direction coil circuit and closing contact P_4' to complete the down-direction coil circuit of the indicator. The coils turn an indicator to show floor numbers, which are illuminated by the light L, connected from the $+04$ to the -01 lines.

Assume the car going in the up direction and approaching the fourteenth floor. Brush CU_1 on the selector picks up the stationary contact on the selector and energizes the up coil in the indicator and the number 14 is flashed into view. Before CU_1 moves off the stationary contact, brush CU moves on and retains the circuit through resistance EMR_2. This is done to reduce the current in the circuit before it is broken, to prevent severe arcing at the contacts. In the down direction, brushes CD_1 and CD close the down direction coil circuit in the indicator.

Floor-call Relays.—At the top of diagram, Fig. 207, are shown floor-call push buttons in the hall- and the floor-relay magnet coils. As previously mentioned, each relay has a magnet coil and a reset coil. For example, magnet coil U_{14} and reset coil US_{14} are the same relay. Assume that the up-direction button U_{14} on the fourteenth floor is pressed. This would complete a circuit for relay magnet coil U_{14} from the $+LS$ through the coil and button

U_{14} to the $-LS$ line. Energizing this coil closes the contact 14 shown between relay reset coil US_{14} and selector stationary contact US_{14}'.

When selector brush CU' touches contact US_{14}', a circuit is completed for the rear coil of switch R, from the $+04$ line through contacts OSa and HL, coil R, contact NS, resistance RR_1, contacts $P2a'$ and CU' reset coil US_{14} and to the $-$ line. Making rear coil on R alive initiates the stopping operations as explained for stopping from the car buttons.

At about the time that brush CU' picked up contact US_{14}', brush SL_1' picks up contact $14FU$. Then, as soon as the pawl

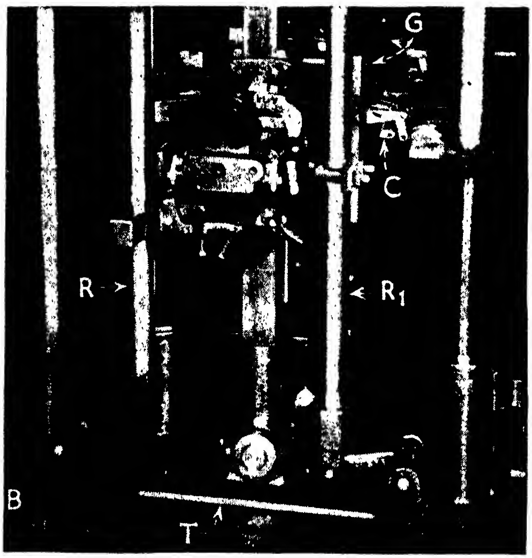


FIG. 213.—Bottom of the selector, showing how vertical U-bolt rods R and R_1 are connected by rod T.

magnet is released and selector contact $1D$ is opened to kill hall-light relay HL, contact HL' closes and the up-direction lamp on the fourteenth floor lights.

The current through reset coil US_{14} with coil R in series is not sufficient to reset the relay. As the car approaches the floor, up reset brush SL_1 picks up selector stationary contact UR_{14} to complete the US_{14} reset-coil circuit, as soon as $1H$ relay opens and closes contact $1Ha$. The reset circuit is from the $+04$ line through the two non-stop buttons, resistance AR_{34}, contacts $1Ha$,

$P2a$, SL_1, and US_{14}', floor contact 14, coil US_{14}, and to the − line. Coil US_{14} being made alive, reset the relay and contact 14 opens to cut out the floor call. Floor calls from other buttons are taken care of in the manner just explained for the fourteenth floor, but with the selector contacts corresponding to the floors and the direction of the car.

Adjusting the Selector.—When the elevator is installed, the floor boards on the selector are properly adjusted and should not require further attention. This adjustment is made by placing the car platform level with the top or the bottom landing. Then, with the selector disconnected from the tape-sheave shaft, its crosshead is adjusted to a position where the floor boards will have to be moved a minimum distance to bring them to a correct position. A floor gage is fastened to the crosshead, and each floor board is adjusted so that it is in exact line with the gage when the car is level with a corresponding floor.

Figure 212 shows the dimensions for a floor gage for a Type 11*SLU* controller and mounted by bolts *G* on the brush panel, Fig. 213. The gage for other types of control may vary slightly from the one shown. If a gage is not at hand, it is well to obtain one from the manufacturers in case checking the position of some of the floor boards should be required.

The normal or release position of the U-bolt rods is adjusted by means of a bumper *B* at the bottom of the selector, Figs. 204 and 213, so that the bell crank that connects to the up rod *R* moves an equal distance above and below a horizontal center line when its pivot is raised $\frac{13}{16}$ in. The tie rod *T* between the two vertical rods is used to accomplish the same adjustment on rod R_1 as given down rod *R*. The bumper and tie-rod adjustments are made at the factory and under normal conditions should not require attention after the equipment is in place.

At the time the floor boards are adjusted, the U-bolts should be set. This is done by raising up U-bolt rod *R* $\frac{13}{16}$ in. and securing the rod in that position. With the rods blocked in position and the car level with the landing the U-bolt on the up rod should be adjusted so that the up pawl just slips under it. On the down rod the U-bolt is adjusted so that the down pawl will just pass over it. There should be no clearance between the U-bolts and the pawls and the U-bolts should be locked securely in place. The pawls are shown engaging the U-bolts at *C*, Fig. 214. Engagement of the pawls with the U-bolts is adjusted by bolts

B. This adjustment should be made to allow the pawls to engage the U-bolts with a firm contact.

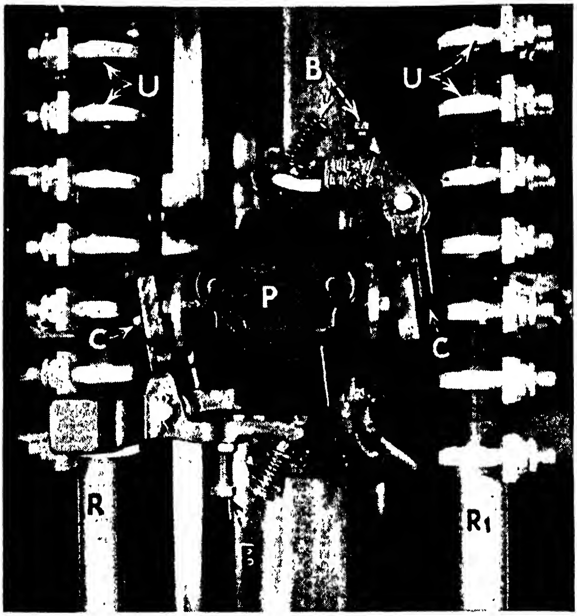


FIG. 214.—Pawl magnet on selector crosshead.

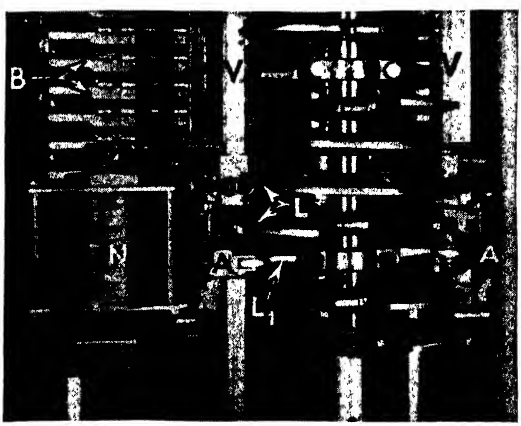


FIG. 215.—Brush magnet on selector crosshead.

When the floor boards and U-bolts are adjusted, also set the cams for the micro-leveling control. With the car level with the floor, the leveling cam is set so that it will be in line with,

and will clear by equal distances, the rolls in the two arms on the selector crosshead. In Fig. 215 cam L_1 is shown in the correct position with relation to the rollers in arms A, when the car is level with a floor landing.

After final setting of floor boards and U-bolts, place the car level with the top floor and mark the position of the crosshead guide arms on the square vertical bars. This marking is necessary and will be found convenient should the tape or chain break on the selector drive. To obtain approximate setting of the selector, the crosshead is run by hand to the marks on the

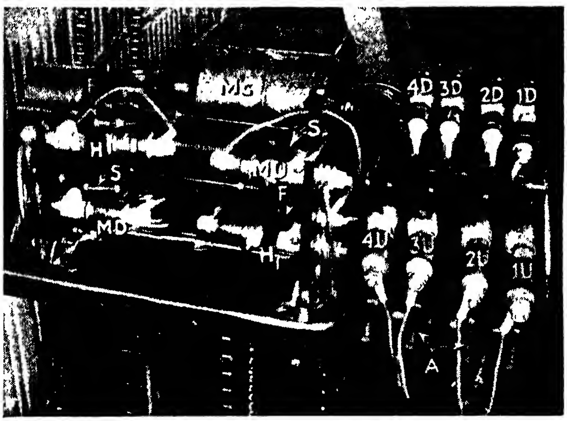


FIG. 216.—Selector top, stopping contacts at right, micro-leveling contacts at left.

square bars and the car set at the top floor. The selector is then connected to the drive and a test made to see how the car levels at the floors. It may be necessary to make changes in the drive to bring the car level with the floors. If the adjustment is small, it can be made by shifting the selector's sprocket wheel on its hub. Where this is not sufficient the chain may be opened and the crosshead moved by the sprocket wheel.

The stopping contacts at the top of the selector are adjusted by adjusting screw A, shown on the front row of contacts, Fig. 216. Similar adjusting screws are on the other row of contacts. Contacts $1U$, $2U$, and $3U$ are adjusted for the up motion of the car, and although these settings vary somewhat for different car speeds, the following are about correct for car speeds of 700 to 800 ft. per min.: Contact $1U$ is adjusted to open when the car is 26 in. below the floor, $3U$ to open when 12 in.

below, and $2U$ to open when it is 5 ft. below. Contact $1D$ may be adjusted with the car moving in either direction and is set to open when the car is within 8 in. of the floor.

Contacts $2D$ and $3D$ are set with the car in the down direction. They are adjusted so that $2D$ opens when the car is within 5 ft. of the floor and $3D$ when the car is 12 in. above the floor. Contacts $4U$ and $4D$ control the opening of the doors and are adjusted to cause the doors to open at the desired time.

Opening of the micro-leveling contacts on the selector is timed by the adjusting screws F on the high-speed contacts and S on the slow-speed contacts. The fast-speed contact H is adjusted to open when the car is 5.5 in. above the floor and contact H_1 to open when the car is 5.5 in. below the floor. In each case the car is moving toward the floor. The two slow-speed micro-contacts MU and MD are adjusted to open when the car is within $\frac{3}{4}$ in. of the floor. Contact MD is for down motion and MU is for up motion of the car.

Distance of Car from Floors When Hall Stopping Contacts on Brush Magnet Engages Floor-board Contacts, Magnet Energized

Car speed, ft. per min.	Up travel, ft. in.	Down travel, ft. in.	Car speed, ft. per min.	Up travel, ft. in.	Down travel, ft. in.
800	17–0	18–0	600	10–8	11–4
750	15–4	16–0	550	9–8	10–0
700	13–7	14–4	500	8–8	9–0
650	12–0	12–8			

The floor-stop contacts on the selector crosshead are carried on the brush magnet. There are two sets of these contacts, one for up motion and one for down motion and each is carried on an adjustable armature on the brush magnet N, Fig. 204. The general arrangement of the brush magnet and stopping contacts is shown in Fig. 217. Stopping operations in floor-to-floor travel is adjusted by screws S and S_1, for down motion. Similar adjustments are made on the top armature for up motion. This adjustment is independent of others and will not be affected by them. The stroke of the magnet is adjusted by screws S_2, so that the car-stopping contacts just make the corresponding floor-board contacts when the car is a distance away from the floor shown in the table.

The contacts shown at *C*, Fig. 213, for illuminating the hall lanterns, the car position indicator, and other signal devices are mounted on an insulating board. This board is slotted so that the contacts may be moved vertically to allow adjustment of each signal device to function at the proper time.

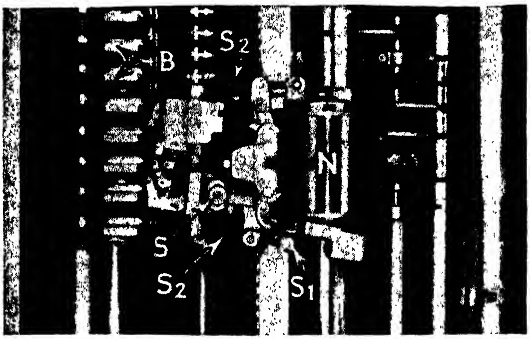


FIG. 217.—Brush-magnet and floor-board contacts.

Judgment must be used in applying the instructions given in the foregoing. The settings suggested are for one type of control; adjustments for other types may vary slightly from those given. If the instructions are intelligently applied, they will be of great assistance to elevator mechanics who have not had an opportunity to become entirely familiar with this equipment.

CHAPTER XVII

ELEVATOR-DOOR OPERATING EQUIPMENT[1]

Good Elevator Service.—Good elevator service often is, fundamentally, maintaining operating schedules. But operators cannot be expected to do this unless elevator hoistway doors operate easily, particularly if they are hand-operated. When hoistway doors are hard to handle, it is difficult to keep good operators, and operators that can be kept will use hard door operation as an excuse for not maintaining schedules and for neglecting their work.

Hoistway Landing-door Hangers.—Hangers on earlier type hoistway landing doors were crude and unsuited to the service, in many cases too light to stand up and with sleeve bearings in the sheaves. All these faults contribute to difficulties in handling and maintenance. Engineering development work has resulted in simple, substantial ball-bearing hangers. Figure 218 illustrates one type. The door is carried on a heavy, steel rail rigidly mounted on the hoistway wall. Running surfaces are finished by grinding, as are those of the oversize ball-bearing sheaves of the heavy hanger. Two sheaves are welded, one near each side of the door, to a heavy steel bar attached by cap screws to the top reinforcing bar of the door. Door-bottom clearance is adjusted by adding shims between door and hanger bar.

Well-designed modern hangers have large-diameter ball- or roller-bearing sheaves. Some bearings are lubricated by grease gun; others are of the self-lubricating type. Hangers are built for one-way opening single-speed and two-speed doors, and center-opening single-speed and two-speed doors, operated either manually or by high-speed power operators. They are usually made in three capacities for medium (up to 250 lb.), heavy (250 to 500 lb.) and extra-heavy (500 to 1,000 lb. doors).

[1] Assistance in preparation of this chapter is acknowledged to Otis Elevator Co.; A. B. See Elevator Co.; Elevator Supplies Co.; Westinghouse Electric Elevator Co.; Gurney Elevator Co.; Wagner Mfg. Co.; and Richards-Wilcox Co.

There is a tendency for doors to be thrust up when force is applied to open or close them. Accurately ground hardened-steel wheels, running on ball bearings, take this upward thrust. Various methods are used to keep this wheel in contact with the lower edge of the rail. The wheel at *W*, Fig. 218, for example, is mounted on a fitting pivoted at *A* to the hanger. An adjusting screw *S*, at the other end of the fitting, raises or lowers the sheave to give desired clearance between wheel and rail. In other types, the upthrust roller runs on an eccentric stud which is turned for adjustment.

Two-speed and Center-parting Doors.—Single doors, supported on two hangers, as shown in Fig. 218, are usually used on small cars and slow-speed doors. This simple arrangement

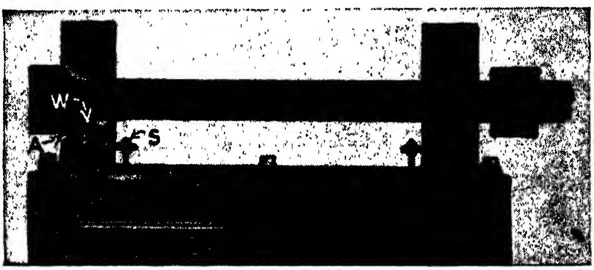


FIG. 218.—Elevator door hanger and top of door.

requires but little operating equipment. Car and hoistway doors for medium-size elevators are frequently made in two sections, opening either from the center (center-opening doors), Figs. 219 and 220, with the doors opening one to each side, or with both doors opening from one side (two-speed doors), Figs. 223 and 227, in which case one section slides back over the other. The center-opening type is simpler and requires but one rail, but if space is limited it will not provide any greater opening than does a single door. If door travel must be confined to car width, then the two-speed type is preferable, for this permits a door opening two-thirds car width. This arrangement requires two tracks, however, and operating equipment is more complicated.

Two-speed doors are never as neat in appearance as single doors or single center-opening type, because one section must lap over the other. If unusually large door openings are required, however, a center-opening two-speed, or even a center-opening three-speed design may be required, even though operating

mechanism is complicated. The three-speed design requires three tracks, the two inner sections passing in back of the outer one as the door is opened.

Where single-speed, center-opening doors are manually operated, some means must be provided to synchronize the movement of the sections. The rack-and-pinion arrangement, Fig. 219, consists essentially of a pinion and two hold-down

Fig. 219.—Pinion and rack connection between center-opening doors.

rollers, all ball-bearing mounted, centered on the rail between the doors. Each inner door hanger carries a pivoted rack engaging the pinion, thus requiring the two doors to operate synchronously.

Another arrangement for accomplishing the same result is shown in Fig. 220. Here the inner or front hangers are joined

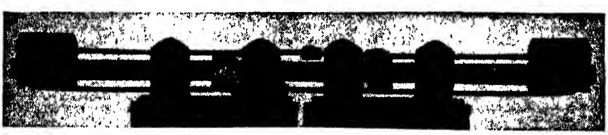


Fig. 220.—Cable connection between center-opening type doors.

by a cable passing over sheaves at the outer ends of the rail. In the figure rubber-covered cable is used to connect the hangers together and to give quiet operation. Others use silent chains.

Hangers and operating equipment are also available for two-speed center-parting arrangements (four doors, two moving in each direction), and for three-speed one-way opening doors (three doors, two passing behind the third), but these are simply more elaborate arrangements of those already described.

Hoistway-door Interlocks.—Arrangements for operating and interlocking elevator doors are legion, so only some common manual types will be described. A vertical-type door-operating bar and interlock, Figs. 221 and 222, combines mechanical lock and electrical interlock so that the latter is forced open when the door is unlocked and is closed when the door locks.

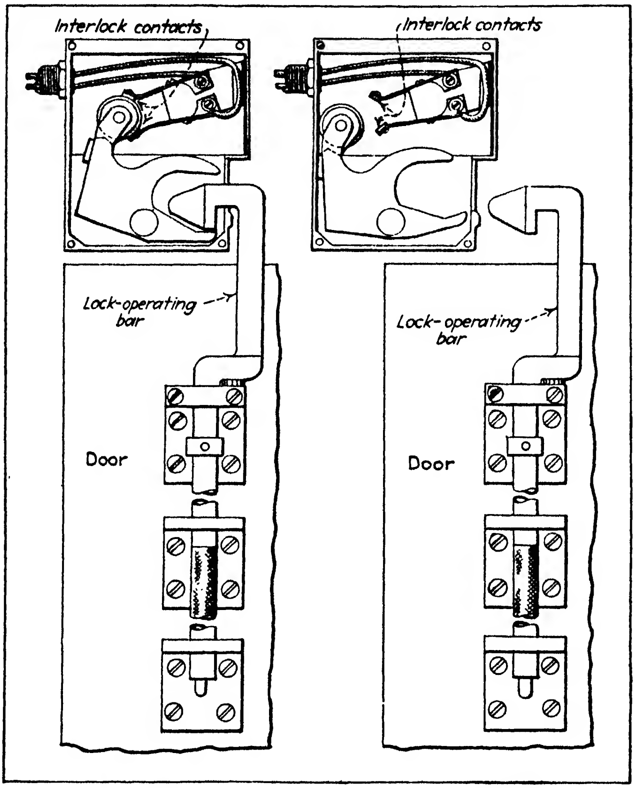


FIG. 221. FIG. 222.

FIG. 221.—Door lock and interlock in closed position.

FIG. 222.—Same as Fig. 221, but lock and interlock are open.

The operating bar is mounted on the door, the interlock on the door frame. Figure 221 shows the door closed, with the lip of the lock latch forcing one arm of the interlock bell-crank down, thus forcing the other arm, carrying the contact roller, into contact. In Fig. 222, the door has been opened, the latch has released the bell-crank, and it has dropped back, opening the interlocking circuit.

Interlock contacts are in series with the car-switch circuit so that the car cannot be operated until doors and interlock are closed. This is essential for safety, because most elevator accidents occur at hoistway doors without interlocks or with interlocks made inoperative. Several states require approved interlocks on car and hoistway door. In these states accidents at elevator doors are almost negligible.

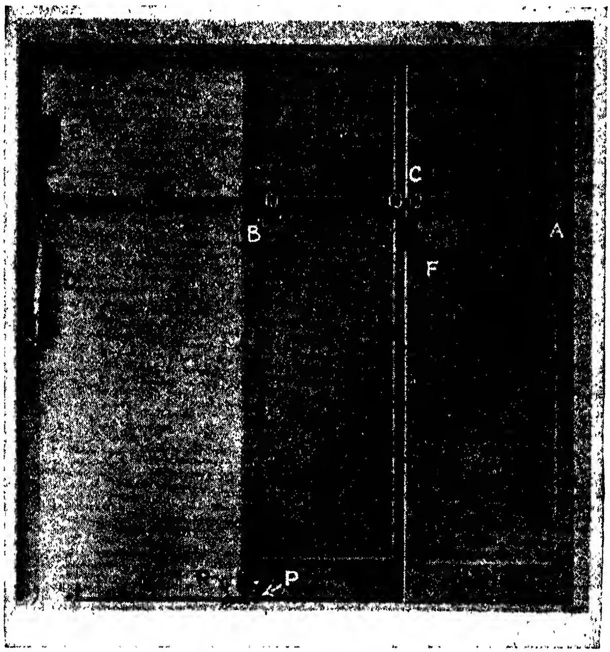


FIG. 223.—Two-speed door and operator in closed position.

Manual Door Operators.—Many types of horizontal manual door operators are used, that shown in Fig. 223 on a two-speed one-way opening door being typical. The operator is fastened to the high-speed door at *A* and to the low-speed door at *B*. The horizontal operating bar is pivoted at *C*, is attached to door-closer *D* and electrical interlock *E* on the door frame. To open the door, the attendant pulls to the left on lever *F*, causing the right-hand door to slide back over the left-hand one, as in Fig. 224.

The inside of the door closer and interlock is shown in Fig. 225. The door closer includes a closing spring attached to the plunger and cylinder bottom. At the lower end of the cylinder is the

retarding chamber into which a piston enters as the doors approach the closed position. Oil in the cylinder damps the closing action. When the doors are opened, the piston is pulled up as in Fig. 224. This puts the spring in tension and fills the dashpot or retarding chamber with oil. When the doors are released, spring tension closes them. The oil damper slows down their motion as they approach closed position to avoid noise or

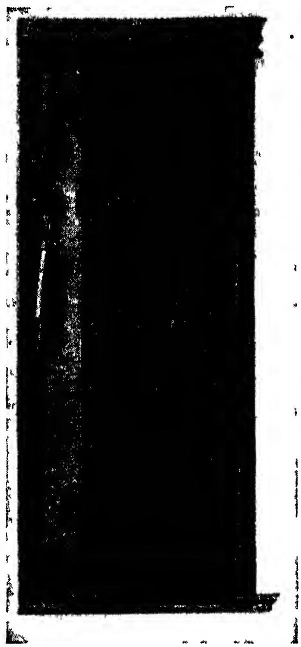


Fig. 224.—Two-speed, one-way-opening doors and their manual operator shown in the open position.

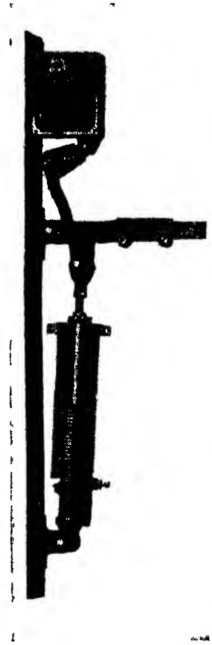


Fig. 225.—Close-up of door closer and interlock shown on Fig. 223.

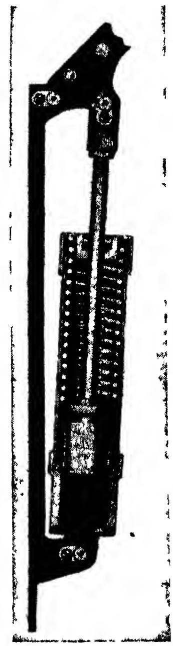


Fig. 226.—Cross-section through door closer.

jar. The interlock switch makes contact as the doors close and breaks it as they open.

Other types of door closers compress the spring as they open, as in Fig. 226. An inner, smaller spring, not compressed until the doors are almost full open, prevents the doors from slamming open. This small spring also assists the larger one in starting closure.

Assuming the doors to be closing, Fig. 226, then the piston is just entering the retarding chamber, meeting the oil and forcing it upward through the annular spaces between piston

and cup and thus checking door speed. This action grows more pronounced as the doors close, thus avoiding slamming. The checking effect can be adjusted by changing piston travel.

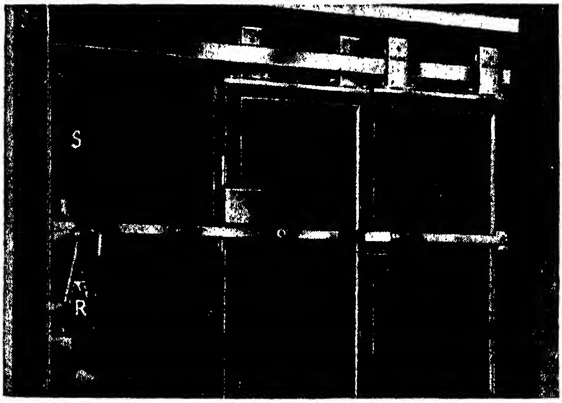


FIG. 227.—Door-closer spring and retarder mounted as separate units.

Other door closers use needle valves or other adjustable devices for the same purpose.

Closing spring *S* is separate from oil-retarding cylinder *R* in the door operator shown in Fig. 227. Thus both spring and

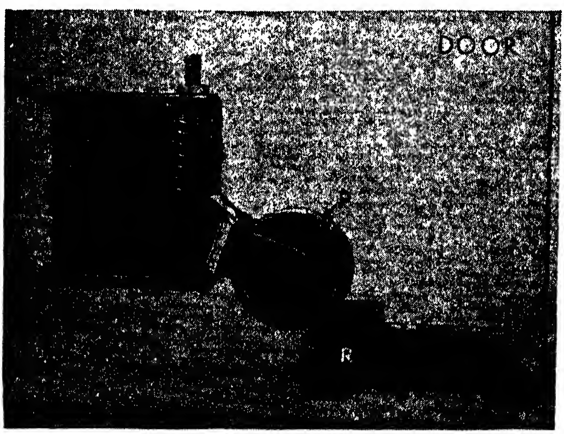


FIG. 228.—Device for holding open elevator doors.

cylinder can be smaller in diameter, allowing the doors to slide past them in opening and giving maximum door opening. The oil retarder acts in both directions, *i.e.*, resists slamming at either full open or full closed position. Additional safety is provided by

the interlock switch which drops open if it becomes mechanically disconnected, preventing operation of the elevator. In this it is similar to the interlock shown in Fig. 225.

Rack-and-pawl arrangements, Fig. 223, are used on elevator doors to prevent doors from being forced open by someone attempting to board the car after the interlock closes. When the doors are within 4 in. of being closed, pawl *P* drops back of rack *R*.

Figure 228 shows a unit for holding doors open. Spring-actuated composition roller *P* drops back of rack *R* on the door sill when the doors are opened and holds them until released by a slight pull by the attendant.

Hoistway- and Car-door Power-Driven Operators.—High-speed elevator service demands and is dependent upon corresponding high-speed car and hoistway-door movement. This means that these doors must be power-operated. Totally inclosed elevator cars make necessary power-operated doors with their controls tied into those of the machine. To obtain highest efficiency in elevator operation, hoistway doors must also be power-operated and move in synchronism with the car doors. When elevators are made full-automatic, at least the car doors must be power-operated and open and close automatically as the car stops or starts. For these and other reasons, rapid advances have been made during recent years in applying power operators to elevator doors.

Practically all earlier types of power operators were compressed-air engines, but modern operators are electrical types, usually motor-driven. There are two general classes: one where individual operators are applied to car and hoistway doors, the other where a single operator handles both car and hoistway doors.

Car-door Operator on Car.—Figure 229 shows a simple car-door operator, consisting of a motor *M* connected to a worm gear *W* which is attached to the car doors by a crank and a system of arms and levers. Operating arm *A* is fulcrumed at *F* and connects to the doors at D_1 and *D*. A connecting rod attaches the top end of arm *A* to the crank on the operator. When the crank is driven in a clock-wise direction, movement of arm *A* around its fulcrum opens the doors by passing one behind the other and moving them to the left. Reverse movement of the operator closes the door.

Control of the door operator is tied in with that of the elevator. As the car stops at a floor, a circuit is completed with causes the operator to open the doors. Movement of the car-operating switch to either the up or down position completes a closing circuit for the door operator. Returning the car-operating switch to the off position before the doors are closed will cause them to open again. This is a safety device which prevents injury

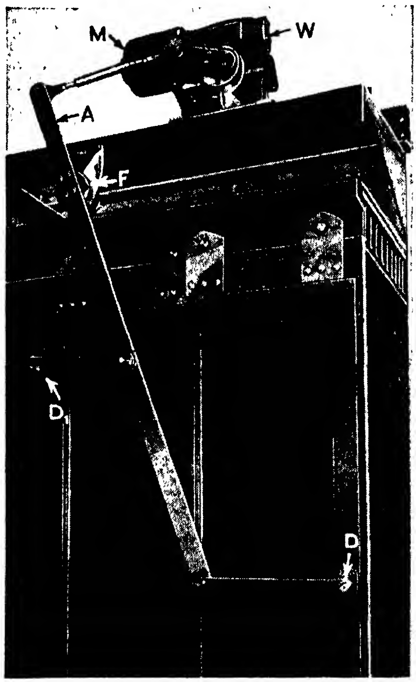


Fig. 229.—Simple motor-driven operator for opening and closing car doors.

to passengers entering the car as the doors start to close. This protection may be obtained automatically by focusing one or more light beams across the elevator entrance on photo-electric cells connected into the door-control circuit. Should a passenger step into the path of the doors after they start to close, they will immediately stop and reopen. The doors can be closed only when the light beam is not interrupted.

Car movement is interlocked with door position so that the car cannot start until the doors are closed. A control panel in the elevator machine room manipulates the door operator and holds its control circuits until the doors are fully closed or

opened. Upon approaching either open or closed position, motion of the doors is retarded by a dynamic-braking action of the operator motor, thus preventing door slamming. In case of emergency the doors may be operated by hand.

On some elevator installations, car doors only are power-operated, the hoistway doors being manually opened and closed by the car attendant. This arrangement has several objects. It tends to slow up elevator schedules, because opening of

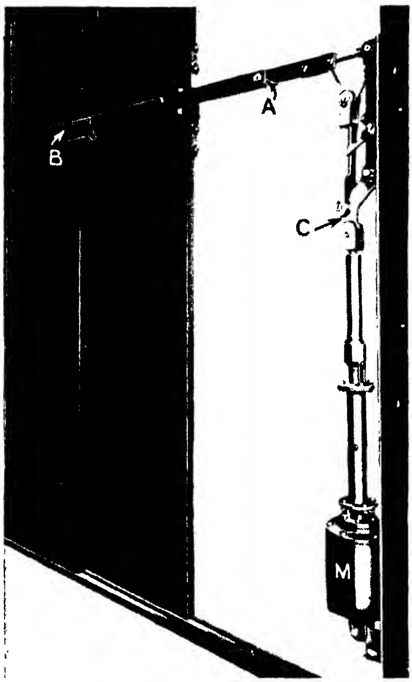


Fig. 230.—Individual motor operator for opening and closing hoistway doors.

hoistway doors must lag behind car-door movement, thus tending to slow up passenger movement. If a passenger starts to get off when car doors start to open, then notices that the hoistway doors are closed against him, his reaction is to stop until certain that the hoistway doors are going to open. If passengers are to leave the car quickly, openings to landings must be cleared immediately when the car stops. This can only be accomplished by having the car and the hoistway doors operate simultaneously.

Operator on Each Hoistway Door.—One way of making hoistway doors power-operated is to install an operator of the type

in Fig. 230. This operator consists of a motor *M* connected by a driving screw to the door-operating bar. It requires space approximately equal to that taken by a standard semiautomatic door closer, Figs. 225 and 226. Control of the operator is initiated from an inductor plate mounted in the hoistway near each landing and an inductor coil carried on the car. (For a description of inductor-plate control see page 42.) When the car is stopping at a floor, the inductor coil is energized, causing the inductor switch to complete the door-operator circuit at that floor and the doors to open automatically. Moving the car switch to the starting position completes a circuit to close the doors. Closing of hoistway doors is under control of the car attendant until the car starts to leave the floor. These doors may also be protected with light beams and photo-electric cells, similar to those used for car doors.

When the operator motor is started to open the doors, Fig. 230, the screw connection between motor and bell crank *C* is lengthened. This causes joint *A* in the door-operating bar to break upward and *B* to move downward, and the doors move open toward the operator. To close the doors, the motor is reversed and the operating mechanism returns to the position shown. Door operation in both directions of travel is by motor power. To prevent slamming, the door speed is checked near the ends of travel by dynamic braking of the motor. Reduced to its simplest form, this equipment is a power operator applied directly to a conventional type of door operator on which all oil checking devices and closing springs have been eliminated.

Operators That Handle Both Car and Hoistway Doors.—Several designs of elevator-door operators use a single power unit to handle both car and hoistway doors. With these designs, means must be provided to connect hoistway-door and car-operating mechanisms so that both doors move simultaneously. With the operator, Fig. 231, shown applied to two-speed, center-opening car doors and single center-opening hoistway doors, a clutch mechanism mounted on a car door at *C* transmits car-door motion to the hoistway doors so that they open and close in synchronism. The operator consists of a motor *M* mounted directly on a worm gear. The right-hand door arm is fulcrumed to the gear case at *F* and the left-hand arm is pivoted at *E*, the whole equipment being supported from the car frame. A crank on the worm-gear shaft connects to the door-operating mechanism

by a roller in link motion *L*. And arm extends from link *L* to a second link motion *L'* and is attached to it by a roller. The operating crank is turned in a counter-clockwise direction by the motor to open the doors. When the car doors start to open, clutch *C* engages a roller on the hoistway-door operating bar, and hoistway doors open simultaneously with the car doors. Full motor power is applied to start the doors and is then quickly reduced to an amount sufficient to keep them moving at a

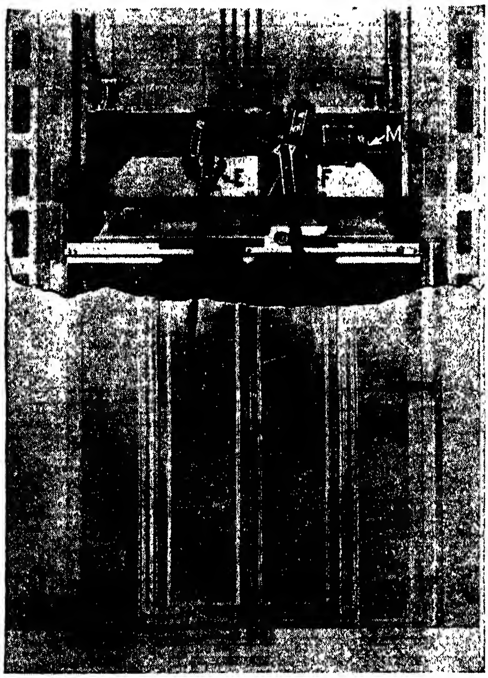


Fig. 231.—Single operator that opens and closes car and hoistway doors.

uniform speed to a point where slow down begins. Two oil check units on the operator provide cushioning action as the doors near their limit of travel in either direction. When the car is moving up or down the hoistway, there is no contact between car- and hoistway-door mechanisms; consequently they cause no noise or wear.

With other designs of car- and hoistway-door operating equipment, the power unit opens the doors only, their closure being caused by springs. A high-speed door operator of this type is shown in Fig. 232. It includes motor *M*, electrical brake

B, worm gear *G*, two eccentrics *E* and limit switches *L*. Car doors are operated by one eccentric and hoistway doors by the other. Fig. 233 shows the operator attached to the car doors. One eccentric on the power operator is connected to arm *A* by

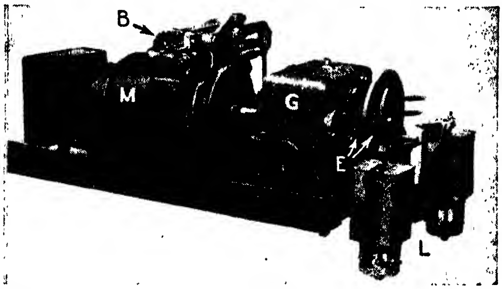


Fig. 232.—High-speed, electric door operator consisting of motor, brake, worm gear, two eccentrics, and limit switches.

chain *C*. As the car comes to rest at a floor, the operator is energized and turns the eccentrics counter-clockwise, pulling arm *A* to the left. This in turn opens the car doors. When the doors have opened, power is automatically cut out of the

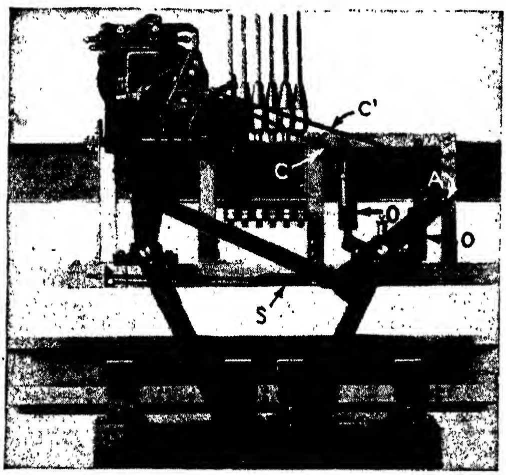


Fig. 233.—Operator, Fig. 232, connected to single-speed, center-opening car doors.

operator and the brake applied to hold them open. When the brake is released, either by a control switch in the car or by moving the car switch to the start position, the doors are closed by spring *S*, which is put in tension when the doors open. Oil

checks O prevent slamming of the doors and insure that they will be operated quietly.

Chain C', Fig. 233, connects the operator to cam H on the car, Fig. 234. When the operator functions to open the car doors, it also raises cam H, which is thrown outward against one leg of bell-crank B mounted on the hoistway door sill. The other

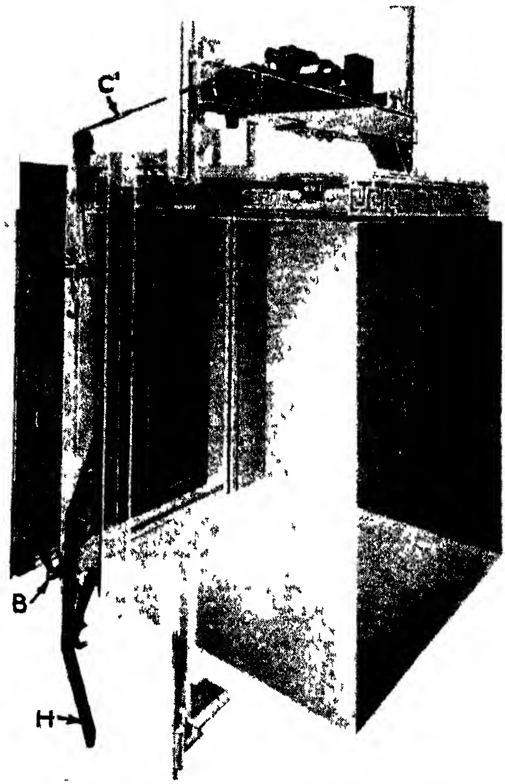


FIG. 234.—Connection of operator, Fig. 232, to single-speed, center-opening hoistway doors.

bell-crank leg is connected by push rods to the hoistway-door operating arm. As cam H pushes one leg of the bell-crank away from the car, its other leg causes joint J in the operating bar to bend upward and open the left-hand door to the left, the right-hand door being moved to the right by a rack and pinion connection at R. Opening the doors puts springs S in tension to close the doors when they are released. Power to open the hoistway doors is applied at right angles to the sill so

that reactions from this force are taken by the door sill and flat side of the car guide, where there is practically no lost motion. Car lurching is avoided. Oil checks *O* prevent slamming at either opening or closing.

When the power operator is installed on self-leveling elevators, the doors open automatically as the car stops at a landing, and close with the first movement of the car switch to the start position (see page 202). Opening of the doors occurs while the car is leveling, the two being so synchronized as to eliminate the passenger tripping hazard. An individual interlock *L* is provided on hoistway and car doors to prevent starting the car if they are not properly closed. Closing of the doors is always under control of the car attendant, and they may be stopped and reversed at any point in their travel.

Other designs of car- and hoistway-door power operators have been developed, but those described give general principles.

CHAPTER XVIII

SIGNAL SYSTEMS

Signal System a Factor in Elevator Service.—Good elevator service cannot be rendered without an adequate and reliable signal system. Such a system must not only provide waiting passengers with a means of signaling their wants to the operator, but it should also indicate when and where they may expect a car. Unless the waiting passengers know where to look for a car, they may be giving their attention to something else when the car arrives at the floor and it may be necessary for the operator to call the passengers before they will know that a car is waiting for them. All such delays tend to reduce the efficiency of the service.

If the operator stops at the floor and leaves without picking up the passengers, it results in unsatisfactory service and complaints. The more closely the operators are in touch with the desires of the waiting passengers and the more exact knowledge the passengers have regarding the position of the cars, the more efficient will be the elevator service. Increasing the efficiency with which the passengers are handled is the equivalent of increasing the speed of the elevator cars. In local service this may be a very important item in maintaining good service, since a large portion of the time is spent at the landings and anything that can be done to reduce this time will improve and speed up the service.

Push Buttons and Bell.—What constitutes an adequate elevator signal system will depend upon the nature of the service, the number of cars, and their speed. Probably the first signal system was for the one who wanted the elevator to shout his or her wants up or down the elevator hoistway as the case might be. In some old buildings this ancient standby is still in vogue today. Figure 235 shows the simplest form of a signal device, which consists of a push button at each floor and a bell located in the car or in the hoistway. When any one of the buttons is pressed, a circuit is closed through the bell. For example, closing the fourth-floor button completes a circuit from the +

side of the battery through the fourth-floor button, to the junction box in the hoistway, through the bell, and back to the − side of the battery. In some cases, such an arrangement is used on freight elevators either to warn anyone who may be using the car that someone on another floor wishes to use it, or the bell may be used to signal the operator by ringing it a number of times corresponding to the number of the floor. Either method is very limited in its application and could scarcely, in the light of modern practice, be given the name of a signal system.

Push Buttons and Drop Annunciators.—Some form of a drop annunciator provides a means of recording the calls made by waiting passengers, and can be used for passenger or freight service where only one or two cars are in use and the service is not exacting. A diagram of connections for an annunciator and bell is shown in Fig. 236. When the button at any of the floors is pressed, the bell will ring and the floor number will be registered on the annunciator. As an example, when the second-floor button is pressed, a circuit is completed from the + side of the battery through the second-floor button, the No. 2 annunciator coil, the bell coil and returns to the − battery terminal. This releases the drop on the annunciator, which indicates the floor and rings the bell or buzzer to call the attention of the operator. One of the shortcomings of this system is that it does not indicate to the operator the direction in which the passengers wish to go. This practically limits the use of a single annunciator to installations having one elevator.

An up-and-down annunciator overcomes some of the foregoing difficulties. This type has two sets of indicators, one for up direction and one for down. At each floor, with the exception of the terminal landings, there are two buttons, one for up and the other for down motion. At the terminal landings there is only one button. At the top landing the button is to indicate down calls, and at the bottom landing the button indicates up calls. A diagram for such an arrangement is shown in Fig. 237.

If the fourth-floor down button, Fig. 237, is pressed, a circuit is completed from the + side of the battery through button 4*D* and to terminal 4*D* in the hoistway junction box. From this box the circuit goes to the car, through annunciator coil 4*D* and the bell coil, returning to the *B*-terminal of the hoistway junction box and to the battery. Energizing this circuit releases the

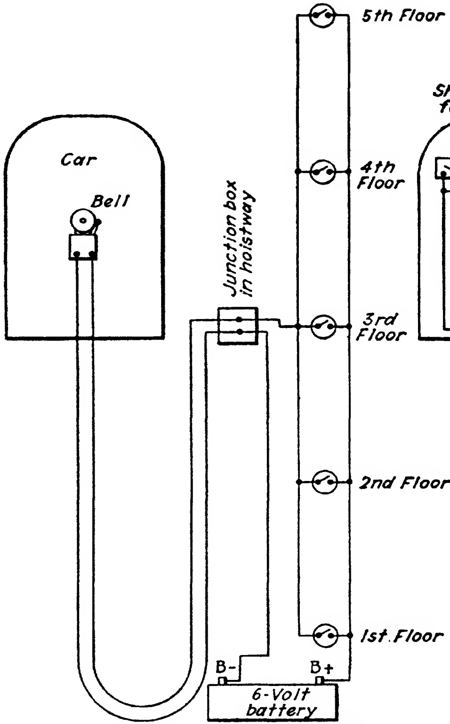


FIG. 235.—Bell and push-button signal system.

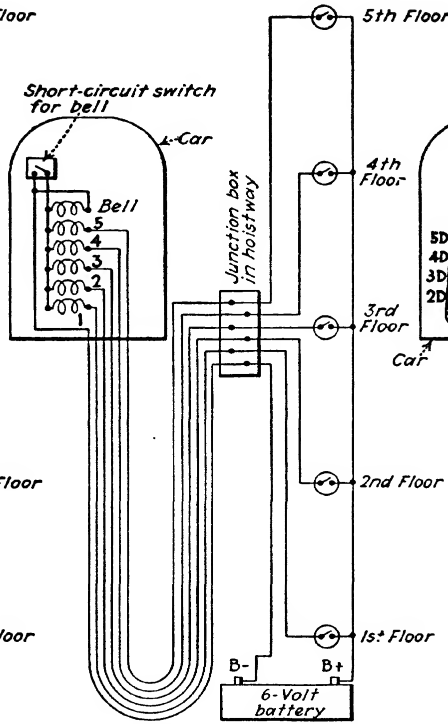


FIG. 236.—Single-bank annunciator signal system.

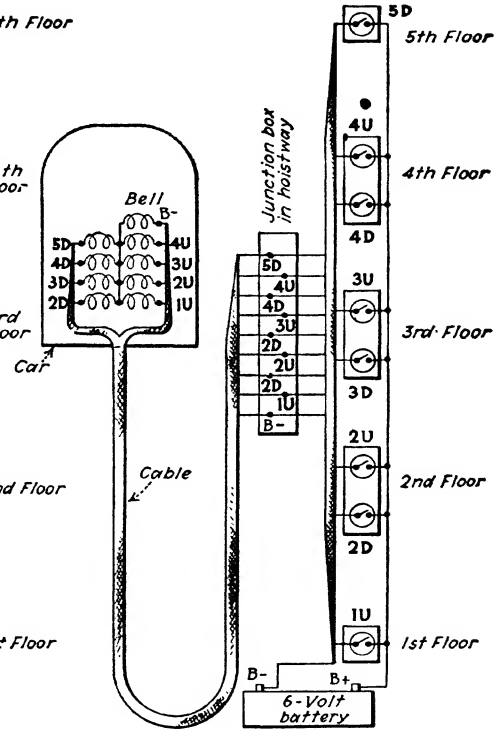


FIG. 237.—Up-and-down direction annunciator signal system.

annunciator drop and rings the bell, the latter attracting the operator's attention to the call.

A passenger pressing the second-floor up button would make a circuit from the $B+$ battery terminal through $2U$ button to the $2U$ terminal in the hoistway junction box. From this box the circuit continues through the $2U$ coil of the annunciator and the bell coil returning to the B-terminal in the hoistway and the battery. This operation releases the $2U$ indicator on the annunciator and rings the bell again calling the operator's attention. From the foregoing, it is seen that this system not only calls the operator's attention to waiting passengers, but also indicates the direction in which they wish to be taken.

On account of the greater information given by this system, it is sometimes used on two passenger elevators serving buildings where the service is not too exacting. When a double-drop annunciator is used on each of two elevators, the same push-buttom arrangement on the floors is used as in Fig. 237, and the annunciator in one car is connected as in the figure. The annunciator in the other car is connected to a junction box in the hoistway as in the figure, and the two junction boxes connected in parallel. For instance, terminal $5D$ of one junction box is connected to $5D$ in the other, $4U$ to $4U$, $4D$ to $4D$, and so on. With this connection, when any one of the floor buttons is pressed, the call will be registered on both annunciators.

In some cases, the annunciator on each car is connected to the same junction box in one of the hoistways. This arrangement has the objection, in case of trouble on one car, of interfering with the operation of the other. If the junction box is in the hoistway of No. 1 car and the signal system to car No. 2 is in trouble, should it be necessary to test from the junction box to No. 2 annunciator it will require stopping car No. 1 to make the test. Likewise, it will be necessary to shut down car No. 1 to renew the traveling cable of No. 2 annunciator. For these reasons, it is best to provide a junction box in each hoistway and connect these in parallel, with a short length of cable.

Objections to the Annunciator System.—An objection to the annunciator system is that there is no means of indicating to the operator of one car when the other car has answered a call. The annunciator does not automatically reset when a call is answered. Since they should not be reset until the operator has answered all the calls in one direction, there is no means of record-

ing a call after the car has stopped at a floor. For instance, assume that the car has a call to stop at the third floor up and after answering this call continues in the up direction; if after leaving the third floor and before the annunciator is reset at the top floor, a passenger on the third floor presses the up button, this call will not be recorded on the annunciator. The drop for the third floor is in the call position from the previous call. When the operator, on reaching the terminal landing, resets the drops, no indication of the third-floor call is left. This difficulty is inherent in all drop annunciator systems and for this reason they are usually limited to single-elevator installations, although in some apartment houses annunciators of this type are used on elevators serving fifteen or more floors and where two elevators are in use.

Bells Used on Annunciators.—The type of bell used on the annunciator may vary with the conditions and the ideas of the one making the installation. Although a continuous ringing bell has the advantage of making certain of attracting the operator's attention to the call, it may be very annoying to the passengers in the car if someone at a landing persists in pressing the button until the arrival of the car. For this reason, sometimes, a short-circuiting switch, Fig. 236, is connected to the terminals of the bell, so that if the bell becomes annoying it can be short-circuited and only the annunciator drops will operate.

A buzzer is of equal value to a bell in attracting the operator's attention, is not nearly so annoying to passengers, and is used extensively. The single-stroke bell is probably equal to any other noise device for attracting the operator's attention and is widely used.

Power for Signal Systems.—Where no other source of power is available, dry cells are used extensively for operating the annunciator signals. These have the objection of failing at inopportune times if not given attention and renewed before they completely run down. They possess the advantage of being readily available and are easily and cheaply replaced. Where a storage battery is available for operating other low-voltage devices, the elevator signal system may be connected to a number of cells in this battery that will give the desired voltage. Although motor-generator sets are used extensively to operate the more elaborate signal systems for elevators, they are rarely used on such systems as previously described. Where alternating

current is available, bell-ringing transformers are frequently used. On account of the inductance of the circuits, an alternating-current voltage about 100 per cent higher than the direct-current voltage should be used. That is, if 6-volt direct current is used, about 12- or 15-volt alternating current will be required.

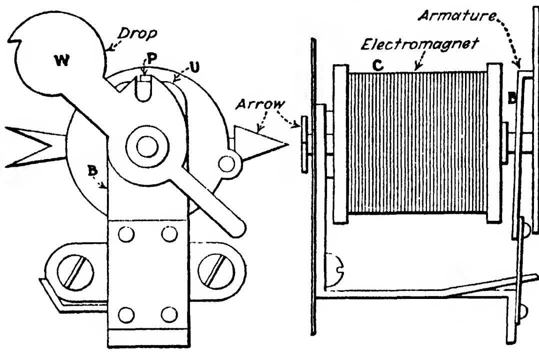


Fig. 238.—Diagram of annunciator drop, indicating arrow in off position.

On some systems, 8-volt direct current is recommended and 24-volt alternating current.

Types of Annunciator Drops.—For use in annunciators a great variety of drops have been developed. The one shown in

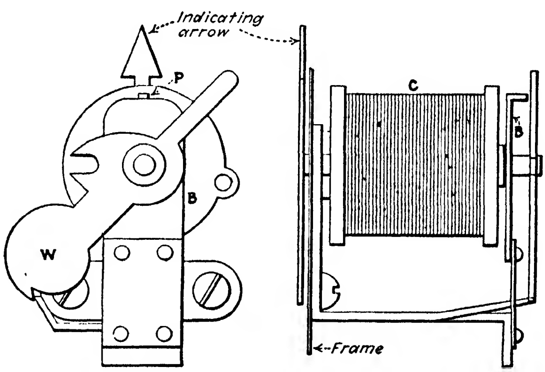


Fig. 239.—Diagram of annunciator drop, arrow in indicating position.

Figs. 238 and 239 will give the general principle. On one end of a shaft that extends through the coil is fastened an arrow, and on the other end of the shaft is a weight, *W*, arranged to turn the shaft about 90 deg. when free. In the off position the weight arm is held by a pawl, *P*, as indicated in Fig. 238. When coil *C*

is energized by closing a push button, it attracts armature B and releases the weight arm W, and it drops to the position shown in Fig. 239. In doing this, the weight arm turns the arrow to a vertical position and gives an indication of the call. When the button is released, coil C is de-energized and armature B returns to its normal position. Drops of this type are reset

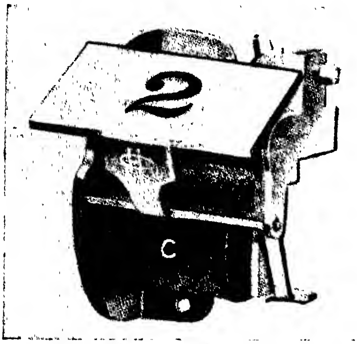


Fig. 240.—Gravity-type drop which is mechanically reset.

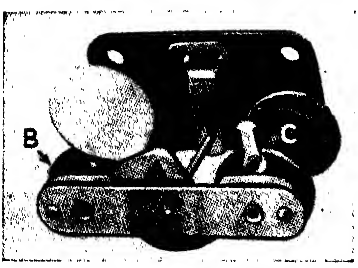


Fig. 241.—Electrical reset type drop.

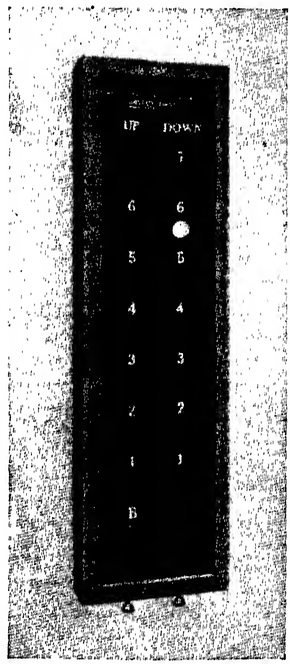


Fig. 242.—Up-and-down type annunciator using drops of the type shown in Fig. 241, but mechanically reset.

mechanically by the operator pushing up on a rod extending below the lower end or through the front of the annunciator case.

Where arrows are used to give the indication, the only change on the annunciator is the position of the arrows, which probably does not possess the qualities for attracting attention and being interpreted correctly as well as a change of color or the flashing of a number. To make the calls on annunciators more readily seen and correctly interpreted, a number of methods have been devised. One of these is shown in Fig. 240. In this design, when coil C is energized, the white target drops down in front of

a transparent opening. With this arrangement, the only indicators exposed are those representing calls and as these are shown by figures against a white target they are easily read.

Another method is to expose a white target in front of a transparent opening, with the floor numbers painted in white above the openings for the targets. A Holtzer-Cabot Electric Company annunciator of this type is shown in Fig. 242, and a drop with

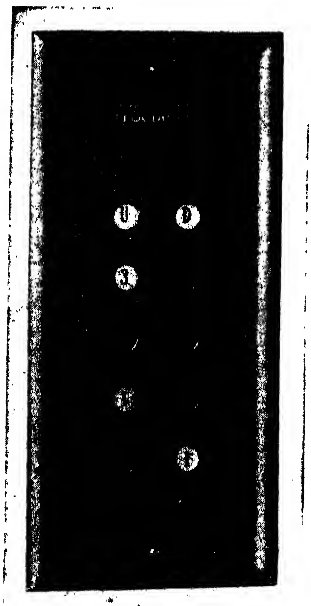


FIG. 243.—Annunciator with drops exposed back of call number.

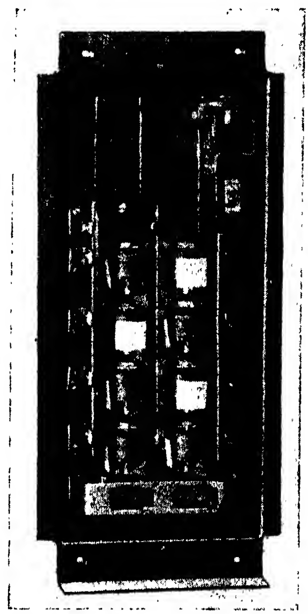


FIG. 244.—Annunciator, Fig. 243, with cover removed.

a reset coil is shown in Fig. 241. When coil *B* is energized by pressing a floor button, the lower end of armature *A* is attracted and the target is thrown to the right and is exposed under the floor number. When the reset button is pressed in the car, coil *C* is energized and the target is moved to the position shown in the figure.

Another system used in elevator annunciators is that of the Elevator Supplies Company, shown in Figs. 243 and 244. The floor numbers are painted in black on transparent glass, then when the white targets are exposed behind the glass, the numbers show up clearly as indicated in Fig. 243. The *U* and *D*, indicat-

ing up and down direction, respectively, have a white background painted on the glass behind the letters. In Fig. 242 the annunciator is arranged from mechanical reset by pushing up on the knobs shown extending below the lower end of the case, while in Fig. 243 the reset knobs are horizontal and are located just below the indicators. Figure 244 shows the annunciator, Fig. 243, with the cover removed. The targets when not exposed are located on the left-hand side of the coils. When the coils are energized, the targets are rotated through 90 deg. into the position shown on three of the coils. A push button for use with the

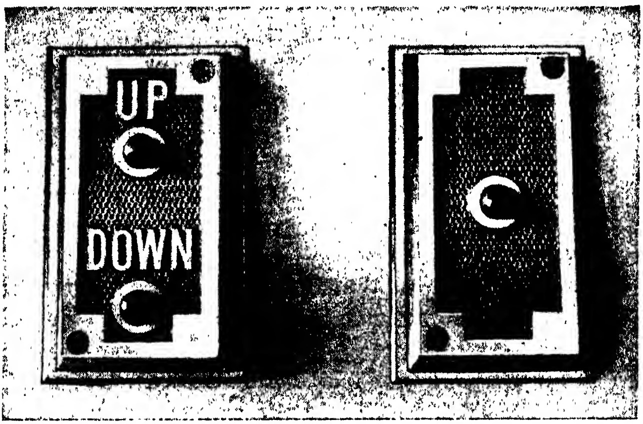


Fig. 245. Fig. 246.
Fig. 245.—Up-and-down annunciator floor push button.
Fig. 246.—Single-bank annunciator floor push button.

annunciator, Fig. 243, is shown in Fig. 245 and a push button for a single bank annunciator is shown in Fig. 246.

Electric-reset Annunciators.—Although mechanical resets are used extensively on elevator annunciators they have a number of objections. First, they are subjected to all the abuse that the operator may see fit to apply. They may be reset by an easy push of the hand or they may be struck a heavy blow according to the temper the operator may be in. Annunciators of the types shown in the figures are designed and constructed for the hard use they are subjected to in elevator service, and will stand reasonable usage. However, elevator operators and mechanics can devise many ways of breaking things if they feel in that state of mind.

Another objection to mechanical-reset annunciators is that they must be located within easy reach of the operator. This is

usually not the position where they can be most easily seen by the operator. The best position is generally on the opposite side of the car gate from the car switch. If a telephone is put on the elevator, this should be near the operator and may interfere with the location of the annunciator, if this also has to be near the same location.

The electric-reset annunciator is coming into quite extensive use and eliminates some of the objections of the mechanical reset. On these types two coils are generally used on each drop, one to give the indication and the other to reset the drop. The reset coils on a single-bank annunciator are all connected in parallel and to a push button, as in Fig. 247, located in a convenient position for the operator. When the operator presses the button, all drops are reset. Up-and-down type annunciators have two reset buttons, one for the up bank of drops and one for the down. Such annunciators can be located in any position most easily observed by the operator; they are not subjected to the abuse of the mechanical-reset type and are more quiet in their operation.

Electrical reset requires that both battery wires be brought to the car, but most annunciator cables are provided with an extra wire that can be used for this purpose. On some annunciators the bell or buzzer is not connected in series with the annunciator coils as in Figs. 236 and 237, but is connected to the contacts of a relay as in Fig. 248. This connection also requires that both battery wires be brought to the car and they can be used also for the electric reset. By putting in the relay as in Fig. 248, the buzzer is taken out of the drop-coil circuits entirely and the only make and break in these circuits is the push button.

In Fig. 248, if a floor button is pressed, a circuit is completed from the + battery terminal through the relay coil, the drop coil and the push button that has been closed to the − side of the battery. The relay contact *A* closes and completes the buzzer circuit from the + to the − side of the battery. It does not make any difference whether contact *A* closes or not; the drop coils will be energized whenever the circuit is completed.

Individual-drop reset annunciators have been used to a limited extent. These require a push button in the car for each drop in the annunciator. Where it is desirable to have individual reset, automatic-reset machines are generally installed and light annunciators of some type are used.

Lamp-annunciator Signal Systems.—Although drop-type annunciators are used extensively in elevator signal systems, they do not possess all the characteristics to make them well adapted to modern systems. Lamp indicators in various forms have come into use. Modern designs of these indicators occupy less space for the same number of floors than the drop type and, when the lights flash on, attract the eye to a greater degree than any of the drop methods.

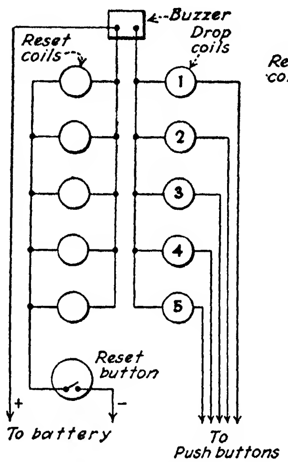


Fig. 247.

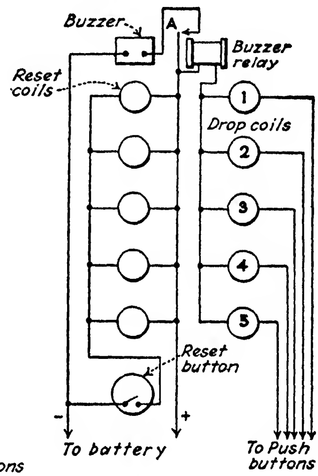


Fig. 248.

Fig. 247.—Diagram of single-bank annunciator with electrical reset coils.
Fig. 248.—Diagram of single-bank annunciator with electrical reset coils and buzzer relay.

With a lamp annunciator some method must be provided to hold the lamp circuits closed, after the floor buttons have been pushed, until the call has been answered and the signal reset. This can be done in two ways. One method uses a relay-type push button, which when pushed, remains closed and completes the indicator-lamp circuit until released by the reset coils located in the push buttons. In the other method the push button, when closed, energizes a relay, the contacts of which light the indicator lamp. With this system the relays are arranged in a central group, which is generally located in the penthouse, and there must be provided a relay for each up or down signal; that is, if there are ten floors there will be eighteen relays. When the indicating-lamp circuit is closed through a relay's contacts, it remains closed until the relay is reset by the reset device.

Relay-type Push-button Systems without Automatic Reset.—Figure 251 is a wiring diagram of a Holtzer Cabot Electric Company's system using the former principle. The reset coils in this system are mounted with the push buttons, as shown at *C* in Fig. 250. One of the two reset coils is for the up-direction signal and the other for the down. On each push button there are three contacts, one for the buzzer circuit, one for the signal-lamp circuit, and one for the reset coil. The operation of the buttons will be understood from *A* and *B*, at the bottom of Fig. 251. When a button is pressed, a pawl *P*, Fig. 250, drops in

Fig. 249.—Front view of relay-type push button.

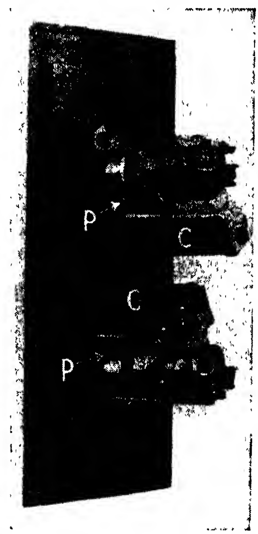


Fig. 250.—Rear of push button, Fig. 249.

back of a collar on the button and prevents the drop and reset contacts from opening as indicated by the position of the up button, *B*. This retains the lamp contact closed until the reset coil *C* is energized and pulls pawl *P* clear of the button, which allows it to return to the normal position as shown in *A*.

The buzzer circuit is closed only as long as the push button is held all the way in. As soon as the button is released, it returns far enough toward its normal position to open the buzzer contacts without opening the light or reset contacts. This is the position of the up button in *B*. Every time the button is pressed to the full-on position, the buzzer will ring.

Assume that, in Fig. 251, the third-floor down button is pressed to the full-on position. Then contacts *A*, *B*, and *C* will be closed. These close a circuit from the + side of the power supply to the connection box in the hoistway and to the third-floor down push button. From the push button one circuit is through contact *A*, into wire *D* and through lamp 3 of the down

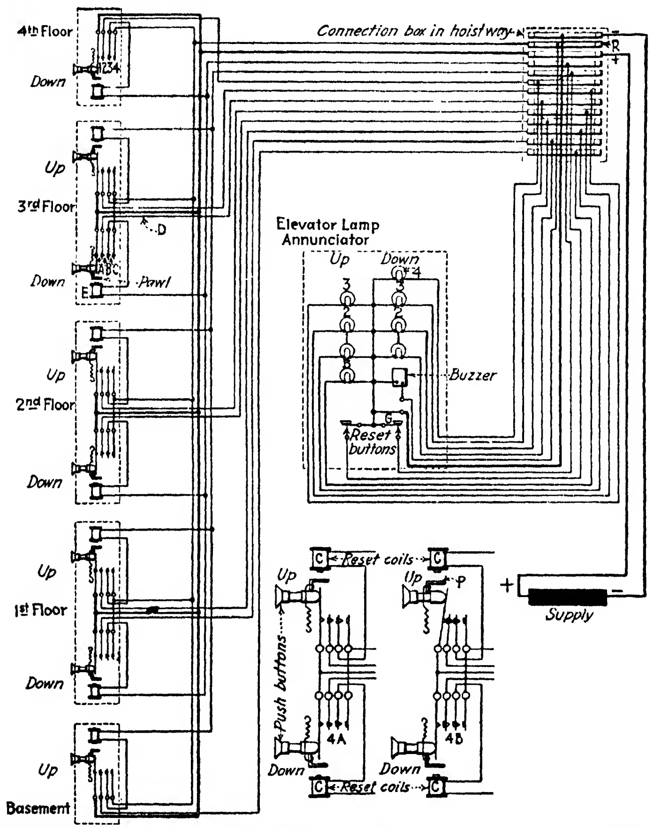


Fig. 251.—Wiring diagram for signal system without automatic reset.

bank in the annunciator and to the − side of the power source. Making this circuit alive lights lamp 3, which shows the location of the call. Contact *B* is connected to reset coil *E*, the circuit for which is open at reset bottom *G* on the annunciator in the car.

As long as contact *C* of the landing button is closed, a circuit is made through the buzzer to the − side of the power supply. The sound of the buzzer attracts the operator's attention to the

call. As previously explained, the buzzer contact remains closed only as long as the push button is held in the full-on position. As soon as the one making the call releases the button, contact C opens and the buzzer stops sounding. Closing push button G on the annunciator completes a circuit for reset coil E, from B through this coil, push button G, and to the $-$ side of the line. Energizing coil E causes it to pull the pawl away from

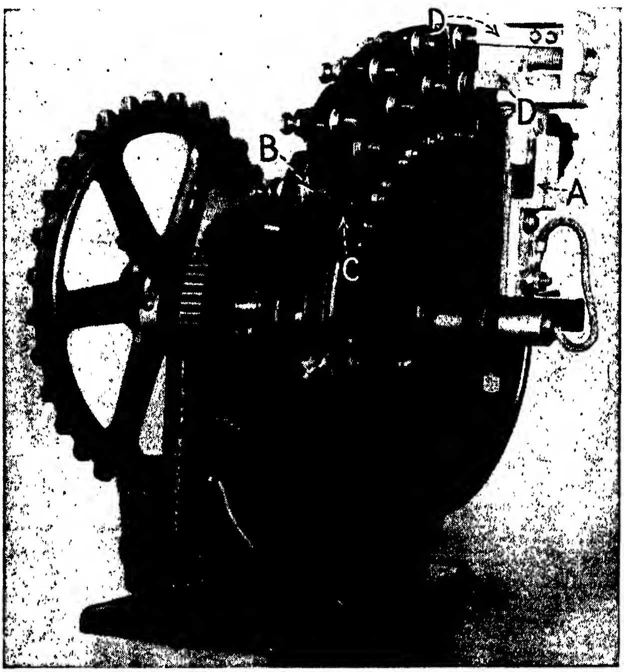


FIG. 252.—Automatic reset machine.

the push button and allows the button to return to the normal open position as shown in the figure, and the third-floor down light on the annunciator goes dark.

It can be seen from Fig. 251 that all the down reset coils are connected to the same wire, so that when reset button G is closed, all the down reset coils are energized and any of the down push buttons that are closed will be released. Similar operations apply to the up buttons as have been explained for the down, except that the up lamps light on the annunciator instead of the down.

Relay-type Push-button Systems with Automatic Reset.—To apply this equipment to two elevators, each machine is wired to its junction box in the hoistway similar to that shown in Fig. 251. Then it is only a matter of connecting the two boxes in parallel; that is the – terminal of one box is connected to the – terminal of the other, *R* of one to *R* of the other, etc. Only one machine

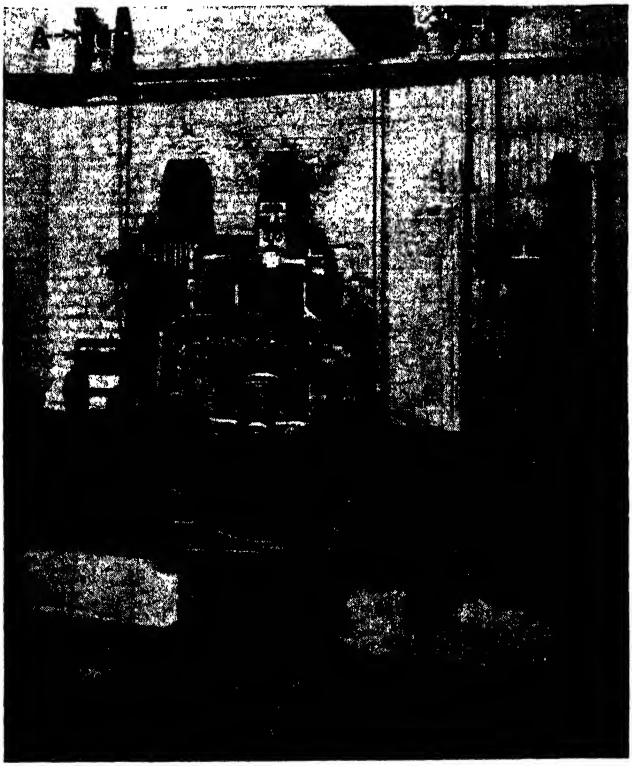


Fig. 253.—Floor-call reset machines are located at *A* and are driven from the elevator machine.

junction box is wired to the floor push buttons, as only one set of these is used for a bank of elevators.

Although this system is simple in its operation, it lacks the individual-reset feature which clears the call on the annunciator when it has been answered. This feature can be obtained by a reset equipment, Fig. 252, driven from the elevator machine. The reset machines are shown at *A* in Fig. 253, and are driven from the traction-sheave shaft by sprockets and chain. A wiring diagram similar to Fig. 251, but with automatic reset,

is shown in Fig. 254. On this diagram if any of the floor buttons are pressed, they will close circuits similar to those in Fig. 251, light the annunciator lamps and sound the buzzer. For example, if the down button on the second floor is pressed, circuits will be energized as explained in Fig. 251.

The reset machine, Fig. 252, is a dial switch geared to the elevator machine by a reduction gearing and chain drive that allow the switch arm *A* to make, on high-rise machines, approximately one revolution when the car travels the length of the hoistway. On low-rise machines the contact arm makes less than one-half revolution, as does the machine in the figure. There are two sets of contacts, *B* and *C*, on this switch, one for the up reset and one for the down. The arm carries two contacts, *D* and *D*, only one of which rests on the stationary contacts at a time. The two contacts on the arm are pivoted in such a way that when the arm is moving in the up direction, the up contact is in service. When the car's direction is down, the other contact completes the down reset circuits, and the up contacts do not close. This is necessary, since with the car in the up motion only the up calls are answered and only these should be reset when answered. Likewise, on the down motion only the down calls are answered and only these should be removed from the annunciator when answered. On traction machines, slipping of the cables on the driving sheave tends to throw the reset machine out of the correct relation to the landings. To overcome this difficulty, at the limit of travel if the arm is out of adjustment, it strikes a stop and a clutch in the drives slips to bring the contact arm into the correct position.

Assume that the second-floor down button is pressed, Fig. 254. This will close push-button contacts *A* and *B* until the call is reset, and contact *C* as long as the one making the call holds the button in the full-on position as previously explained. Contact *C*, when closed, completes a circuit from the + side of the power source, to the connection board in the hoistway, through contacts *A*, *B*, and *C* of the second-floor down button and returns to terminal *B* in the hoistway connection boxes. From these boxes circuits go to each car, through the buzzer and returns to the connection boxes in the hoistway and to the − side of the power source. In this particular installation the annunciator is wired to a terminal board under the car, where the buzzer is also located.

The second-floor down-landing lamp circuit is through contact *A*, on the push button to *A* terminal in the hoistway connection boxes. From *A* in each hoistway connection box there is a circuit to each car, through down lamp No. 2 and returns to the — side of the power source. This operation lights the second-floor down lamp on each car and indicates to the operators the floor where the call is made.

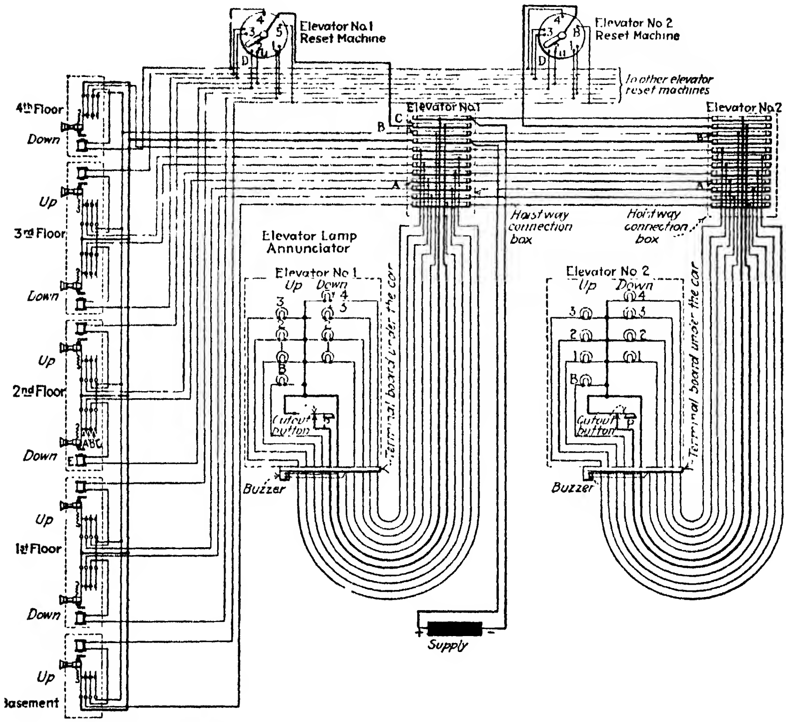


Fig. 254.—Wiring diagram of signal system with automatic reset machine.

If No. 1 car is coming down, when it reaches the second floor the operator should stop and answer the call. With the car in the down motion the contact arm of No. 1 reset machine is moved until it rests on contact 2*D*, about the time the car reaches the second floor. With the arm of No. 1 elevator reset machine on contact 2*D*, a circuit is completed through contact *B* on the second-floor down button, reset coil *E* and to contact 2*D* of the reset machines. If the arm of machine No. 1 is resting on this contact, the circuit is completed through the arm to terminal *C*

in the hoistway connection box. From this terminal there is a circuit to push button P in No. 1 car back to the connection boxes in the hoistway and to the − side of the power source. Completing this circuit energizes the second-floor down reset coil E and causes it to release its push button, and the down No. 2 lamp on each annunciator goes dark, indicating that the call has been answered. What has been said regarding the second-floor down button applies to any of the other call buttons.

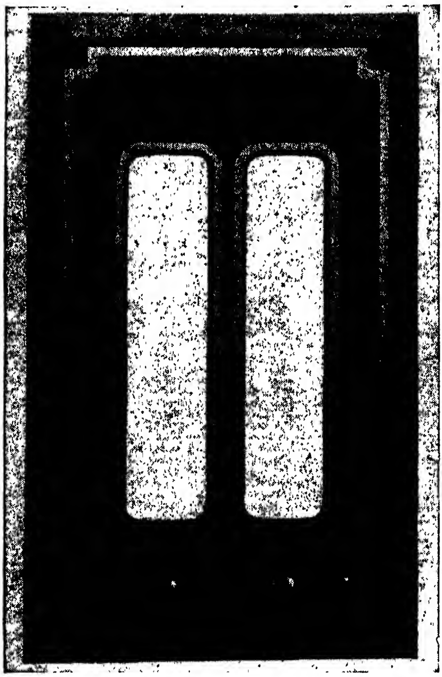


FIG. 255.—Front view of lamp annunciator.

Cutout button P can be used by the operator to prevent the reset machine from removing the signal from the system. For example, assume No. 1 car coming down and on leaving the third floor it had a full load of passengers. When the car passes the second floor, the reset machine will clear the down signal for this floor. To prevent this the operator holds button P open, which breaks the reset circuit and prevents the second-floor down signal being cleared. The signal remaining on No. 2 annunciator shows the operator that the second-floor down call has not been answered.

In a high building the conventional type of signal-light annunciator becomes unwieldy in length, particularly if the signals are arranged in an up and a down row. To provide an annunciator that is compact, the Holtzer Cabot Electric Company has developed one in which the floor numbers are back of a special glass and are caused to become visible by lighting a small lamp, back of each number. A front and an internal view of one of these annunciators is shown in Figs. 255, 256 and 257. The front

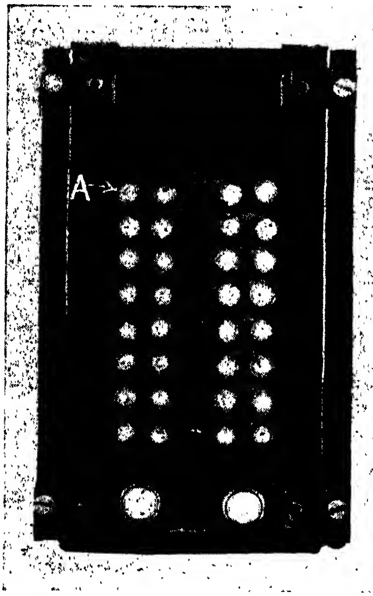


Fig. 256.

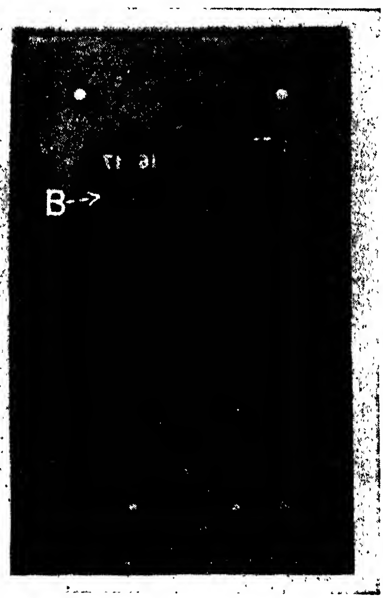


Fig. 257.

Figs. 256 and 257.—Inside of annunciator, Fig. 255, showing the signal lamps and their cells.

of the annunciator, Fig. 255, has dimensions of 5 × 9 in. and on an exposed glass surface 1 × 5 in. the signals for sixteen floors are given for one direction. The lights shown at *A*, Fig. 256, are inclosed, back of the floor numbers in round cells, as at *B*, Fig. 257. The floor numbers in the light cells can be seen on the left in Fig. 257. This system is designed to operate on 12 to 14 volts direct or alternating current.

Signal Systems Using Conventional Push Buttons and Separate Relays.—In the two systems previously described, the relay is built into the landing push buttons. Several systems have been developed that use conventional-type push buttons and separate

relays. A wiring diagram of such a system, manufactured by the Elevator Supplies Company, Inc., is shown in Fig. 260. When a waiting passenger pushes a button to signal the operator, a light is energized in an annunciator on each of the cars, as with the systems in Figs. 251 and 254. These lights remain in circuit until a car has gone by the floor in the direction indicated by the signal, when the signal is removed from the annunciators automatically.

For each floor there is an up and a down relay except for the terminal floors, which have one relay each. One of these relays is shown on the right in Fig. 260, with two coils *A* and *B* and a mercury contact pot *M*. Coil *A* is connected to a floor button, and *B* to the reset machine. When coil *A* is energized by a passenger pressing a floor call button it attracts its armature *C* and releases armature *D*, which falls by gravity and makes contact in the mercury pot *M*. In this operation the right-hand end of armature *D* rises and locks *C* in the closed position, where it remains until coil *B* is energized. When armature *D* makes contact in the mercury pot, it completes a circuit for the light annunciators in the cars to indicate the floor to the operators. The lights remain energized until the operator leaves the floor from which the signal was given and in the direction indicated.

If a signal is given for a car to stop at a certain floor in the down direction, the first car that goes about three feet below this floor makes a contact in a reset machine that energizes coil *B* in the relay. The magnet attracts armature *D* and releases *C*, which takes the position shown in the figure and retains the contact out of the mercury pot, thus removing the signal from the annunciators in the cars.

Relay Reset Machine.—The reset machine consists of two rows of contacts, *A* and *B*, Fig. 258; one for the up and the other for the down signals. Brushes *C* are moved over each set of contacts. When the car is in down motion the brushes are in contact with the down contacts only. On up motion the brushes shift from the down to the up contacts. By this arrangement signals are reset in the direction only in which the car is going.

The reset machine is driven by a sprocket chain from the end of the drum shaft. The brushes are carried on a screw shaft *S*. On this shaft the sprocket has a clutch that slips to compensate for slippage of the cables on traction elevator machines. If the cables slip and throw the reset machine out of adjustment, the

screw shaft runs against a stop before the car reaches a terminal landing and is prevented from turning. For the remaining travel of the car to the terminal, the clutch in the screw shaft slips. In this operation the brushes are brought into correct adjustment. The brush carriage rides directly on the driving screw and is prevented from turning with the screw by stops *D*. These stops are set so that when the direction of the screw is reversed the brush carriage is moved far enough in the screw's direction of rotation to transfer the brushes from one row of contacts to the other.

Only one bank of relays is required regardless of the number of cars, but a reset machine is needed for each car. When a floor

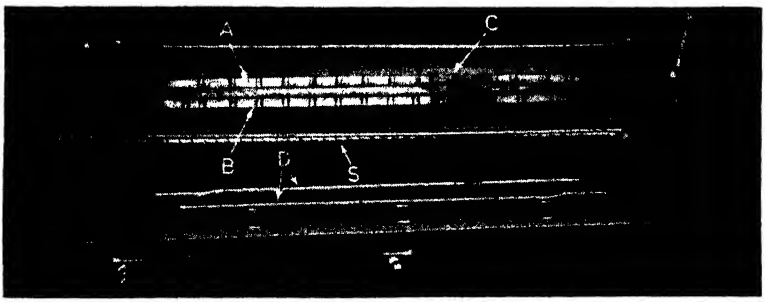


Fig. 258.—Machine for automatically resetting the signals after the floor calls have been answered.

call button is pressed it registers a signal on the annunciator of all cars. The reset machine on the first car answering the call removes the signal from the annunciator in all the cars. Thus the operators are kept informed of the calls to be answered.

Relay Panel.—Figure 259 shows a relay panel for a 14-story building. The relays in the lower bank *A* are for one direction and those in the upper bank are for opposite direction of travel. The small switch *C* is for the night bell in the hoistway. At the top of the panel is the 220- to 10-volt motor-generator for supplying power to the signal system. The 2-pole switch on the right is on the lights in the floor lanterns and the 4-pole switch controls the car signal circuits.

Operation of a Signal System.—A study of the wiring diagram, Fig. 260, will make the foregoing discussion clearer. Either 10-volt direct current or 12- and 20-volt alternating current may be used. In either case two devices are usually provided to supply the power and are connected with a double-throw switch

so that either one may be used on the system. Assume that the power supply is direct current, then two motor-generator sets are provided to convert the 110- or 220-volt direct current into a 10-volt supply.

If a waiting passenger on the fourth floor presses the down button, a circuit is formed from the + side of the power switch

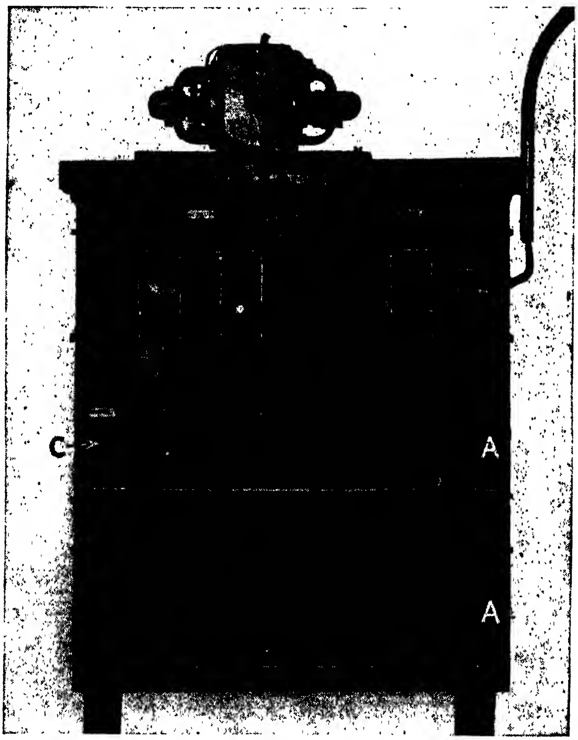


FIG. 259.—Relay panel for elevator signals in a 14-story building.

to the common connection between the two buttons on the fourth floor. From here the circuit continues through the down button, the push-button magnet on the 4*D* mercury pot, the night-bell relay coil and to the − side of the power switch.

Energizing the push-button magnet releases the contact and it drops into the mercury pot to complete a circuit for the fourth-floor down signal light in the cars' annunciators. This circuit is from the + side of the switch to the S-connection in the hoistway junction box. From the junction box a conductor goes to the common connection between the up and the

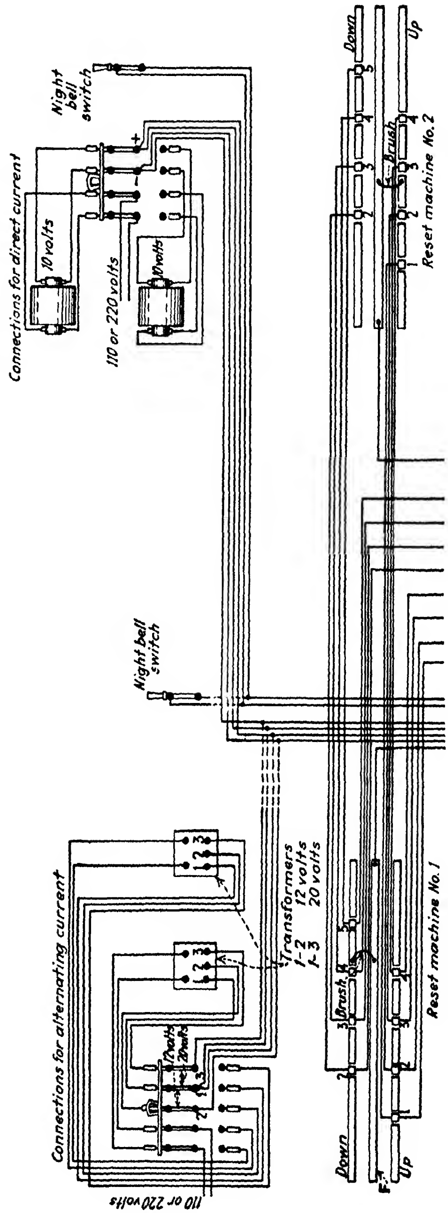
down signal lights in the annunciators of all cars. The circuit is then through No. 4 down lights back to the 4*D* terminal in the hoistway junction box, the 4*D* mercury pot, the busbar under this pot and to the − side of the line. The same circuit is energized to the annunciators in all the cars and the fourth floor down signals are set. In this way each operator knows where the passengers are waiting.

There is a buzzer at the top of each annunciator that may be used if desired to give the operators an audible signal. The circuit for the buzzer is from between the signal lights to the *B* terminal in the hoistway junction box through the contacts of the night-bell relay and to the − side of the line. The night-bell relay contacts are closed when a floor button is pressed, consequently the buzzer will ring only while the button is held closed.

Sometimes a night bell is installed in the elevator hoistway to call the attention of the night watchman, who may also be operating the elevator. This bell circuit is controlled by a single-pole knife switch on the signal system in the elevator room. When the night-bell switch is closed, as in the figure, pressing any of the floor buttons will ring the bell and give a signal on the car annunciator. The circuit for the night bell is from the common wire for the floor push button through the bell's coil, the night-bell switch, the night-bell relay contacts and to the − side of the line. The night-bell relay contacts are closed only while a push button is pressed, therefore the bell will ring only when a button is closed.

The circuits for the other floor signals can be traced as explained for the fourth floor down call. When a floor button has been pressed and a signal set on the annunciators, it remains until a car has gone to the floor in the direction of the call. When a car is a short distance past that floor, a contact is made in the reset machine that energizes the mercury pot magnet and opens the contact corresponding to the floor and the direction in which the car is going.

Assume that No. 1 car answers the fourth floor down call: The circuit for the reset magnet is from the common connection between the annunciator lights through the circuit breaker to the C_1 terminal in the hoistway junction box to the busbar *F* in No. 1 reset machine. With No. 1 car in down motion, the brush in the reset machine makes contact between the down row of contacts and busbar. This brush will move from right to



Connections for direct current
10 volts
10 volts
110 or 220 volts
Night bell switch
Night bell switch
Down
Up
Brush
Reset machine No. 2
Transformers
1-2 12 volts
1-3 20 volts
Connections for alternating current
12 volts
20 volts
110 or 220 volts
Brush
Reset machine No. 1
Down
Up

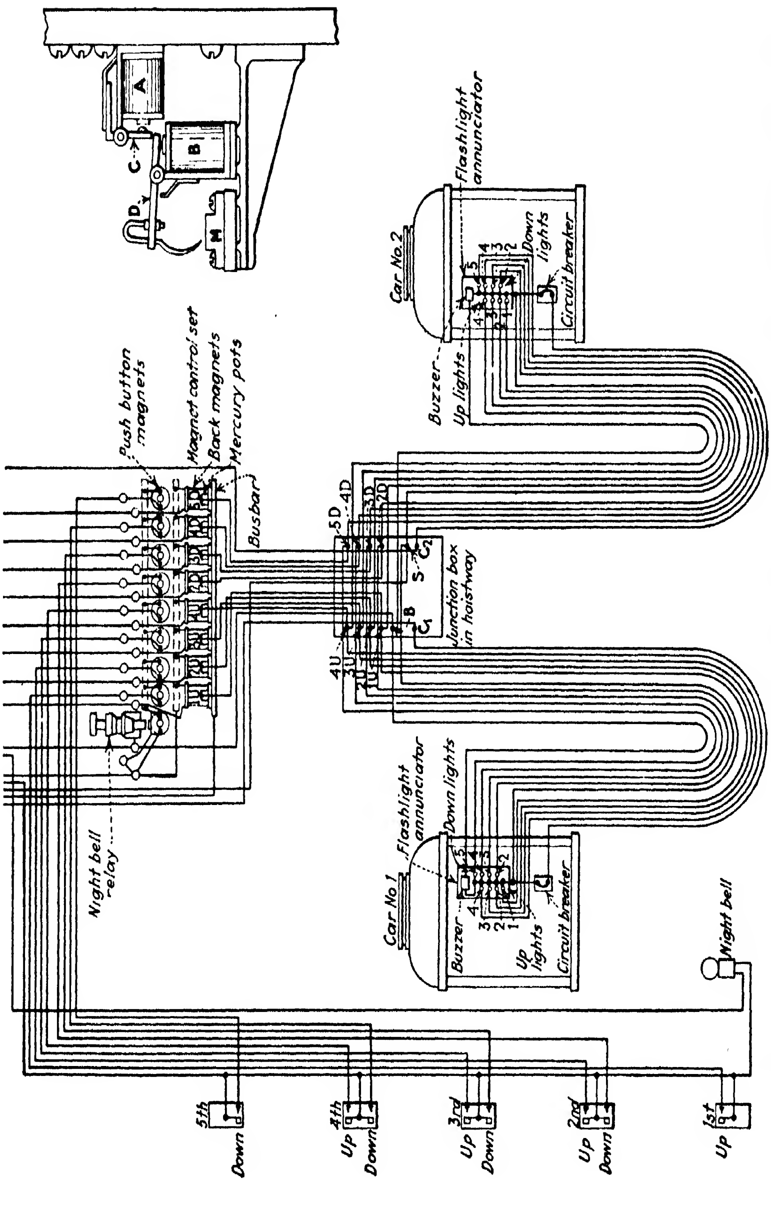


Fig. 260.—Wiring diagram for a flashlight-annunciator signal system with automatic reset.

left as the car travels downward. When the car is a short distance below the fourth floor, the brush in the reset machine comes on to contact 4 and completes the circuit from this contact through coil 4*D* on the mercury pots and to the negative side of the line.

Energizing coil 4*D* causes it to lift the contact out of the mercury pot, and the No. 4 down signal lamps on the annunciators go dark. This shows the operator on No. 2 car that the down call on the fourth floor has been answered.

The circuit breaker in each car is a push button that allows a car to pass a floor without resetting the signals. For example, if No. 1 car left the top floor with a full load and did not stop to answer the call from the fourth floor, pressing the circuit-breaker button would hold the reset circuit open and the signals would remain on the annunciators of the following cars.

In the diagram, Fig. 260, down contacts 2, 3, 4, and 5 on reset machine No. 1 are connected to down contacts of the same number in reset machine No. 2. Cross connecting the machines allows either to reset signals, depending upon which elevator answers the call.

When alternating current us used, 12 volts is supplied for the lamps, as from poles 1 and 2 of the switch, on the left, and 20 volts is used on the magnet coils across poles 1 and 3. On account of the magnet coils' inductance, about double the voltage is required to operate them on alternating current as on direct current. The inductance of the light circuits is low, and only a slightly higher voltage is required than for direct current.

Signal systems of this kind are used for groups of one or more elevators in buildings, such as hotels or office structures, where the service may be intermittent and the elevators do not always make complete trips. Where the elevators are intended to make complete trips, an operator's signal-light system is frequently used. Details of other types of signal systems are given in Chapter XVI on signal control with micro-leveling.

Elevator-car Schedules.—A building may have a sufficient number of elevators, but if they are not used efficiently, the service will be unsatisfactory. An adequate signal system is essential to the operation of modern elevators. Operators must be informed as to where the waiting passengers are and the direction in which they wish to go. It is also necessary for waiting passengers to know when cars are approaching and the directions in which they are going.

It is of equal importance to operate the cars on a proper schedule. Unless this is maintained at all positions in the hoistway, the service will be erratic—too many cars may be passing a given point in the hoistway, while at other points the service is inadequate. Service may be irregular even when the cars are controlled at the ground floor by a starter.

Manual Dispatching.—As an example of how the elevator service may vary under manual dispatching, a check taken in one building showed that the departure time varied from 30 to 80 sec. between cars leaving the ground floor. In some cases the delay between cars was two and one-half times as long as it was at others. The service at the intermediate floor was even more uncertain. For instance, a check taken at the seventh floor showed that the time between cars passing this floor in the down direction varied from 30 to 120 sec. This variation occurred in a building where if the cars had been run on schedule the interval between them in either direction would have been about 50 seconds.

The preceding figures show that the off-schedule time tends to increase as the cars travel up and down the hoistway. Even though the interval between departures at the ground floor did not exceed 80 sec., up in the hoistway the maximum time was 120 sec. This is what is to be expected, since the car leaving the floor after a long waiting period would generally have a greater number of passengers to deliver, and more passengers would have accumulated on the intermediate floors for the car to handle. All of this tends to slow down the car on its trip up and down the hoistway. Slowing this car up allows the following car to catch up with it, and two cars may answer the same signal from a given floor, which adds further confusion to the service.

These conditions emphasize the necessity of uniformly dispatching the cars from the ground floor and maintaining this schedule throughout the trip. It is practically impossible for a dispatcher to do this. And he usually has many other duties to perform in serving the passengers, all of which distracts his attention from the problem of having the cars leave the floors on a definite schedule.

Automatic Car-dispatching Systems.—In recent years considerable attention has been given to relieving the starter of dispatching the cars, making operation automatic and providing means to show the operators if they are running on schedule.

Such a system of automatic elevator control has been developed by the Elevator Supplies Company, Inc. In each car there is a three-light unit, Fig. 261, containing a green, a red, and a white light. The green and the red lights are for dispatching the cars at the terminals, and the white lights show the operators if the schedule is being maintained. The machine for operating

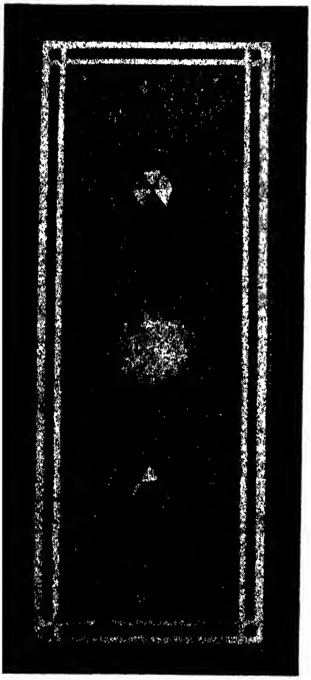


FIG. 261.—Car-operator's dispatching signals.

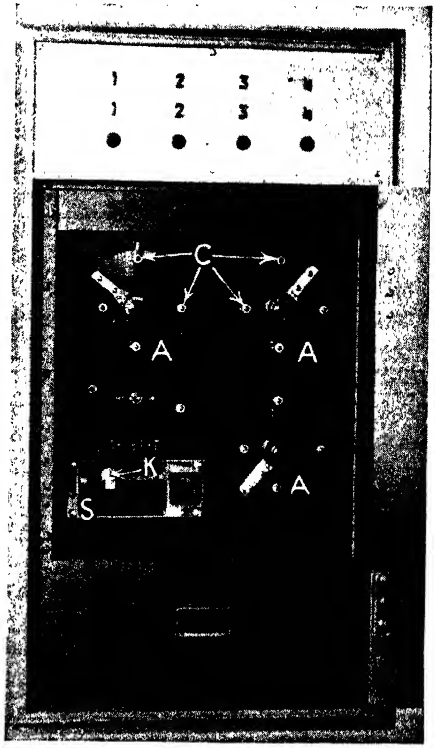


FIG. 262.—Machine for automatically scheduling a bank of elevators.

the system is shown in Fig. 262. It consists of three motor-driven arms A for flashing the lights. In the top of the cabinet are duplicates of the green, the red, and the white lights in the cars. Below these lamps is a set of starter's call-back buttons, which are connected to the green light in each car. The dispatching cabinet is near the starter's station on the ground floor.

The dispatching machine is designed for scheduling a group of three to five elevators. The dispatching machine, Fig. 262, is designed for scheduling four elevators. For a group of four elevators, with contacts C placed in the end of the arms, they

will make contact with buttons 1, 2, 3, and 4 and give signals to all four elevators. If the arms are properly spaced the cars will be dispatched on equal time for either direction. For example, if the round-trip time is 180 sec. the cars will be signaled to start at 45-sec. intervals. When it is time for elevator 1 to start a green light will flash in that car. When it is time for the operator to leave the top floor a red signal will flash in his car. This will be 90 sec. after the car leaves the ground floor. When the car should be half way down the hoistway the white light will flash. If the car is above the half-way point, the operator knows that he is behind schedule. On the other hand, if the car is below the half-way point the signal shows that the schedule has been exceeded. Forty-five seconds after No. 1 car leaves the ground floor the operator in No. 2 car will receive a green signal to leave. Similarly, 45 sec. after No. 2 car starts, No. 3 will get a signal to go. This system of equal up and down time is the one that is normally used between rush periods. With this set-up the arms that flash the green, the red, and the white signals make one revolution in 180 sec.

In rush periods the up and the down traffic is out of balance. During the morning-in and noon-in periods traffic is virtually all in the up direction, while during the noon-out and evening-out periods the traffic is very largely in the down direction. To take care of these conditions the red and the white lights can be adjusted to allow a longer running time in the direction of heavy traffic. For instance, if the round-trip time is 180 sec., the arms on the automatic dispatcher may be so placed that the time in the direction of heavy traffic will be 100 sec. and in the opposite direction 80 sec.

Instead of using the white lights to give an intermediate signal to the operator, it may be employed to give a preliminary starting signal at the lower terminal landing. When used for this purpose, the white light flashes about 4 sec. before the green light. Generally a buzzer is arranged to ring when the green starting light flashes. It has been found that the chance of an operator missing a signal at the ground floor is many times that at the others, on account of the heavier traffic at the former. Where the cars run to a basement floor the white light may be used to signal the leaving time from this floor and the green light used for the usual purpose at the ground floor.

The schedule may be speeded up or slowed down by adjusting the position of knob K in schedule selector S, Fig. 262. This

adjustment is simple and can be easily made. If a car is taken out of service, the schedule can be quickly adjusted for the lesser number of cars by rearranging the contact keys *C* in the numbered sockets. A chart on the inside of the machine's inclosure door gives the socket numbers for dispatching the different numbers of cars that may be in service.

The green and red lights at the top of the dispatching cabinet, as previously mentioned, correspond to those in the different cars and flash in synchronism with them. These show the starter if the car operators are getting the signals to start at the terminal landings. The call-back buttons are connected to the green lights in the cars. When a button is pressed it causes the green light in the car, corresponding to the button, to flash, and at the same time the operator receives an audible signal. Code calls may be worked out between the dispatcher and operators to suit the particular conditions under which the cars operate.

While it is important the cars leave the terminal landings on schedule, the intermediate floors are of equal importance. This is particularly true where passengers are waiting on the floors. When they press the button, they expect almost instant service, regardless of the fact that the elevators are serving other floors at that instant. Even though it is not possible to give a perfect service, automatic scheduling insures intermediate floor service that approaches terminal floor timing within 10 sec. This additional time is necessary to cover the irregularities of the traffic in a building for which it is not always possible to make immediate adjustment. Usually the maximum waiting time at the intermediate floors will approximate the terminal timing interval or may even be less during the periods of uniform travel in both directions.

An automatic dispatching system is best adapted to groups of four or more elevators. Its installation will increase the efficiency of the elevator service over that of manual dispatching and give more satisfactory service. Equal spacing of the cars in the hoistway will allow the regular signal system to operate at its greatest efficiency by preventing cars from overrunning each other and making false stops. It is also possible to hold the parking time at terminals to a minimum, and keep the cars in operation a maximum of time. This allows of handling a greater traffic with the same number of elevators than is possible with manual dispatching, or the same traffic may be taken care of with a smaller number of cars in service.

CHAPTER XIX

LOCATING FAULTS IN THE MECHANICAL EQUIPMENT

Noisy Operation.—Mechanical troubles on electric elevators are not so numerous as are electric and in general are not of such a nature as to cause an immediate shutdown of the machine. However, these defects are in many cases of great importance so far as the safety of operation is involved, and therefore the mechanical parts of the machine should be given as careful attention as the electrical.

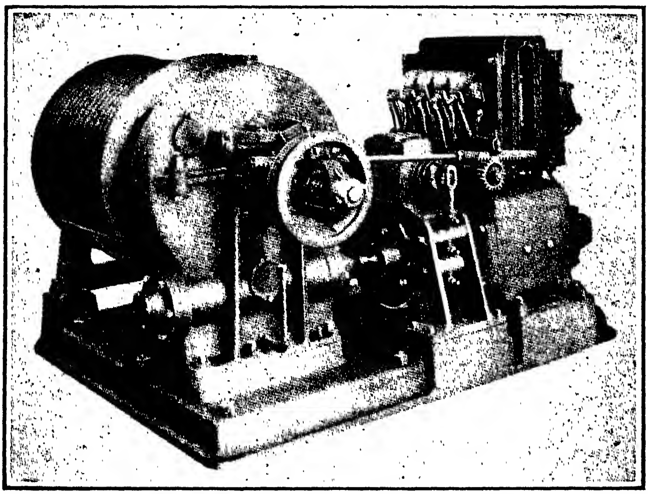


FIG. 263.—Drum-type elevator machine.

The mechanical troubles that can develop on an electric elevator depend upon the type of machine. With a geared-type drum machine, Fig. 263, or the geared traction machine, Fig. 264, the motor and gears are common to both types and what is said regarding one applies to the other. Noisy operation of the motor is a common defect. This may be due to the rotating element's

being out of balance or the bearings worn so as to let the armature or rotor rub on the polepiece or stator core. The latter is more likely to occur with induction motors than with direct-current machines, on account of the close clearance between the rotor and stator of alternating-current machines.

Another cause of noisy operation is the armature or rotor working loose on the shaft. In elevator service the rotating element of the motor is subjected to reverse stresses, due to starting in one direction and then in the other, and the braking action during stopping. If there is any slight movement of the armature or rotor on the shaft, it will soon wear to allow considerable motion. When there is any movement between the rotor and the shaft, it should be corrected as soon as possible by shimming up under the key or by fitting a new key. If the repair is not made at an early stage of the trouble, both the key and keyseats will become worn and it will be necessary to recut the keyseats and use a larger key. If the rotor has not a large shaft and a substantial key, it may be found difficult to prevent the rotor from working loose on the shaft. This was particularly true of some of the older types of alternating-current motors that were constructed with short large-diameter rotors.

The motor out of line with the wormshaft is one of the most common causes of noisy operation. This is a dangerous condition if the motor is much out of alignment, since the bending strains set up in the rotor shaft at the brake-wheel coupling may break the shaft. If this were to happen with a heavy load in the car when in the down motion, the motor would be acting as a brake to keep the load under control. Should the rotor shaft break, the load would be released, and since the mechanical brake will not be applied until the operator centers the car switch, there is the possibility that the car may reach a high speed or even get out of control or the safeties set on the car before the operator acts. In cases where dynamic braking of the motor is used to assist the mechanical brake in stopping, if the armature or rotor shaft breaks, only the mechanical brake is available for stopping the machine.

Brake Wheel and Brake.—The brake and brake wheel should be given careful attention, for it is this part of the machine that stops the car, and if the brake is not in proper condition, not only is the service rendered by the elevator impaired, but a hazard to life and property is created.

It should be ascertained if the brake wheel and coupling are properly secured to the motor and wormshaft. Two of the common troubles with a brake are, it does not stop the car quick enough or it stops it too quickly with an unpleasant jar to the passenger. The failure of the brake to stop the car within proper limits may be due to worn or oil-soaked and dirty brake lining. Putting a new lining in the brake shoes should not be attempted except by an experienced mechanic. Unless the lining makes a good fit with the shoes, it will have an uneven surface and will

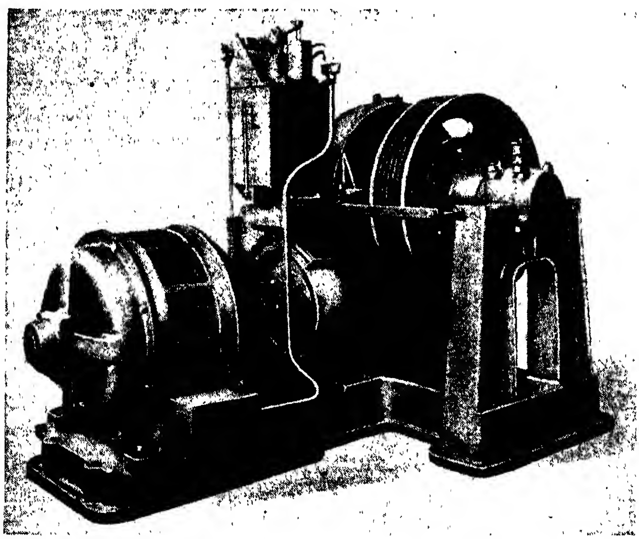


FIG. 264.—Geared-type traction elevator machine.

touch the brake wheel at only a few points. As a result the effectiveness of the brake will be greatly reduced.

When the brake linings are in good condition and the brake does not properly stop the car, the cause is then in the mechanical adjustments or in the dynamic-braking circuit in the controller. The brake should be adjusted so that when it is released, the shoes just clear the wheel. Then the tension springs or the weight should be adjusted to give the desired stopping period.

Where dashpots are used on the brake to control the rate of application, it is essential that they are kept clean and in good condition or their action will not be constant, which will cause differences in the application of the brake. If the dynamic-

brake circuit should open, it will, with the same mechanical brake adjustment, allow the car to slide. If the mechanical brake is adjusted to stop the car within reasonable limits under this condition, an unpleasant jar to the car will result. A short-circuit in the dynamic resistance will stop the car too quickly, but this will generally be accompanied by sparking at the motor's brushes. Therefore, when trouble is being experienced with a brake, careful consideration should be given to the electric circuits as well as the mechanical features.

On some types of brakes it is possible to have one shoe applied with greater force to the brake wheel than the other. A brake adjusted this way will stop the car suddenly in one direction and allow it to slide in the other. On some of the old-type machines with no, or with very little counterweight and a brake with only one shoe, it is impossible to obtain a satisfactory adjustment of the brake.

On alternating-current equipment with two-speed motors, on stopping the high-speed motor is cut out and the slow-speed motor is cut into service. This motor acts as a brake to slow the machine down to correspond to the motor's normal speed. If the control equipment gets out of adjustment so that the slow-speed motor is not cut into service for slowing down, then the entire work of stopping the machine is thrown on the mechanical brake, with the result that it will be difficult to make good stops, and the extra work put on the brake may cause it to heat excessively.

At best the stopping of elevators driven by alternating-current motors is not any too satisfactory. In the high-speed direct-current machine the elevator is brought almost to a stop by the motor before the mechanical brake is applied. In this equipment the desired application characteristics can be designed into the electrical circuits of the brake, so that the car will be brought to rest smoothly under almost any conditions of load and speed. On alternating-current equipment the machine cannot be slowed down by the motor below that corresponding to the speed of the slow-speed motor, which is usually one-half or one-fourth of full speed, except in some modern machines a speed ratio of 6 to 1 is used. From the slow speed of the motor the rest of the slowing down and stopping must be done by the mechanical brake. On alternating-current equipment the brake does not lend itself to the fine adjustments as does the direct-current brake. There-

fore, it could hardly be expected that as smooth stopping of the elevator would be obtained with alternating-current equipment as with direct current.

Thrust Bearings.—On the worm-gear type of drum or traction machine the thrust bearings are one of the chief sources of trouble, particularly in the older types of machines. These thrust bearings may be of the disk type, Fig. 265, made up of bronze and steel disks, or of the ball type, Fig. 266. In the latter the ball thrust bearings are shown at *T*. If the disk thrust is properly designed and installed and kept well lubricated, the wear should be relatively small. Whatever wear there is, must be taken up by the adjusting screw. If the wear is all on the back thrust bearing, then each time the adjustments are made the worm and motor shaft are brought back to their original position. When the wear is on the front thrust bearing, then the wormshaft and

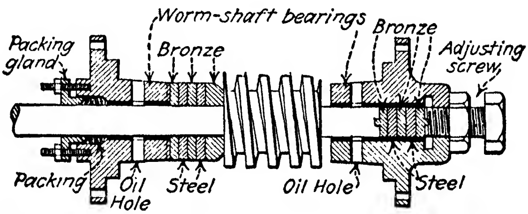


Fig. 265.—Wormshaft, showing bronze- and steel-disk thrust bearings in place.

motor shaft is being pushed toward the outboard bearing of the motor. In this case care must be exercised to see that the motor shaft is not pushed far enough endwise to transfer the thrust from the thrust bearing to the outboard bearing of the motor. If the outboard bearing of the motor is allowed to take the thrust, this bearing may heat, or in severe case the thrust may be sufficient to break the bearing bracket.

In some of the older-type machines one of the thrust bearings was put on the outboard bearing of the motor, but on these machines the motor was designed for such service. This arrangement did away with the thrust bearing on the front end of the wormshaft, which cannot be got at without taking the wormshaft out, which is generally a job that requires considerable time.

With the ball or roller thrust bearings, one of the chief difficulties has been chipping of the balls or rollers. The troubles have been very largely overcome in the more modern designs. Chipping of the balls or rollers was not all due to defects in these

parts, but in the adjustment. In assembling the machine all the end play can be taken out of the wormshaft and still have it turn freely. This did not provide for expansion of the wormshaft when its temperature increased during operation, and the expansion no doubt put sufficient load on the balls to crack them. In adjusting a ball thrust bearing, about $\frac{1}{32}$-in. play should be allowed for expansion of the wormshaft.

In addition to the two types of thrust bearings shown, a great variety of other types have been developed, but for the most part

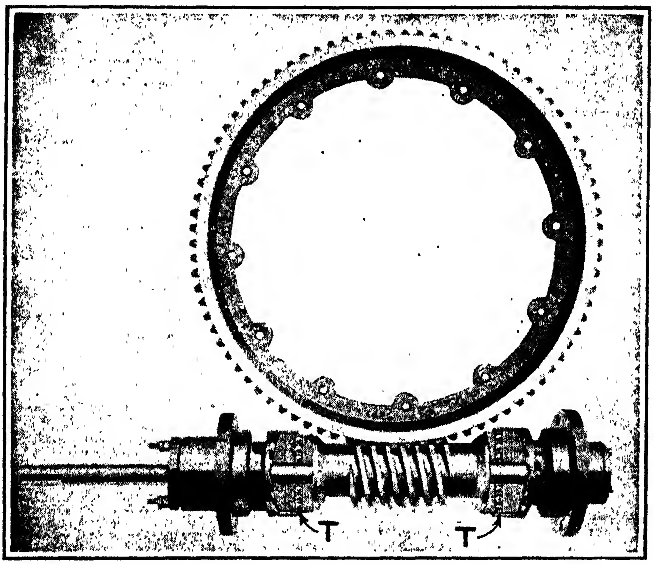


FIG. 266.—Wormshaft, showing ball thrust bearings in place.

they differ in features of application and adjustment rather than in principle. There has been used a number of different types of adjustable thrust bearings for the motor end of the wormshaft. Another scheme that has attracted a great deal of attention is that of locating both thrust bearings on the rear wormshaft bearing, where they are easily accessible for making repairs and adjustment.

Tandem-geared Machines.—On tandem-geared machines, Fig. 267, the gears not only mesh into the wormshaft, but they mesh into each other, as can be seen in the figure. In this arrangement the thrust is taken in the gears and wormshaft and

no thrust bearings are required. Assume that the right-hand gear, which is attached to the drum, has a tendency to turn clockwise owing to the difference in loading of the car and counterweight cables on the drum. This would tend to thrust the wormshaft to the left and turn the left-hand gear in a counterclockwise direction. This gear tending to turn in a counterclockwise direction sets up a thrust in the wormshaft to the right, which opposes the thrust set up by the other gear, consequently the worm shaft cannot move on end in either direction. This arrangement works

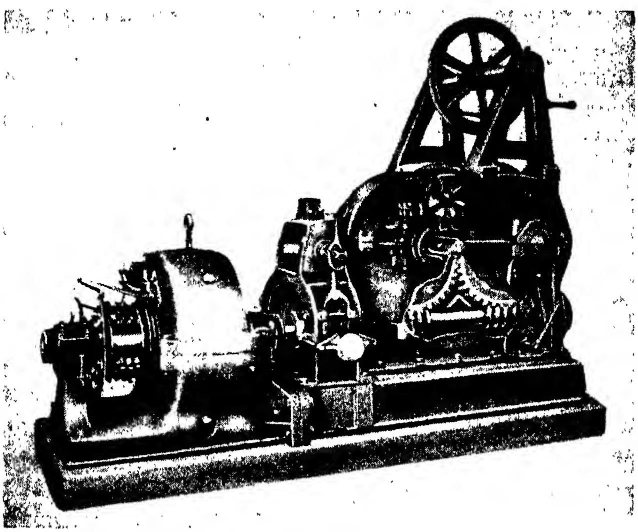


Fig. 267.—Tandem geared drum-type elevator machine.

out very well as long as the gears are not worn, but as soon as these parts begin to wear it allows a backlash in the gears, which permits a certain amount of end motion of the worm shaft. There is no way that this end thrust can be taken care of except by installing thrust bearings or renewing the gears, the latter being an expensive job. The more the gears wear, the greater the wormshaft end play becomes.

Worm and Gear.—No attempt should be made to work on the wormshaft or thrust bearings until either the car or the counterweight is bottomed in the hoistway, whichever is the heavier. In modern machines this will always be the counterweight. If the gear is allowed to get out of mesh with the worm, the counter-

weight being the heaviest will fall, with disastrous results unless they are supported from the bottom of the hatchway. When work is to be done on the drum-shaft bearings the counterweight should be supported from the bottom of the hatchway and the car slung from the overhead beams, using two chain falls for the latter.

Where the gear and worm do not mesh properly, or when they are not properly lubricated, they may begin to cut; in which case the gear and worm operates with a loud roaring noise and vibration. This trouble can be cured by putting one or two pounds of sulphur in the gear case with the oil and letting it remain until the operation of the gears becomes normal. The length of time will depend upon the elevator service. If the machine is in continuous operation, then one-half to one day's time will be sufficient to put a good wearing surface on the gear and worm. After this the oil is removed from the gear case and the case and gear thoroughly cleared, before a new supply of oil is put in. Chipped balls in a thrust bearing will cause the machine to make a noise similar to that obtained when the worm and gear are cutting, but nothing will cure the thrust-bearing trouble except renewing the defective parts.

When it was general practice to key the worm gear and drum to the drum shaft as separate units, considerable trouble was experienced with these parts working loose on the shaft. In modern practice the drum is keyed to the shaft, but the gear is bolted to a heavy flange extension on the drum's hub. With this arrangement the only source of trouble is the bolts working loose, which hold the gear to the drum. If the bolts are properly tightened and the nuts locked in place, loose gears are a rare occurrence. However, on inspections, this part of the machine should be looked at carefully, since a failure at this point would be dangerous, as the car would be free to go in whichever direction the excess weight, in the counterweight or car, would take it.

Wearing of the Grooves in Traction Sheaves.—On traction machines using metal sheaves, either of the geared type, Fig. 264, or the direct type, Fig. 268, the wearing of the grooves in the traction sheave to different diameters is a source of trouble, as it affects the life of the cables. Where the grooves have unequal diameters, the ropes on the smaller-diameter grooves must slip a certain amount to maintain the same speed as those running on the larger-diameter grooves. This slipping tends to increase the

wear and make the conditions worse. Not only are the grooves worn, but the cables will wear to different diameters.

When the grooves become worn, it is the practice to remove the sheave, take it to a machine shop ane turn the grooves to the proper shape and equal diameter in a lathe. In some cases the lathe tool is mounted on the elevator machine and the grooves trued up in place, using the motor to drive the sheave. Either

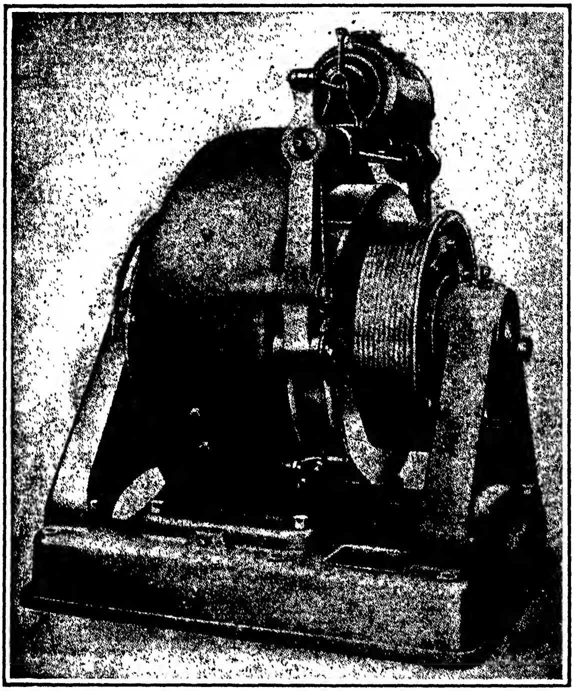


FIG. 268.—Direct-traction type elevator machine.

method requires shutting down the machine and removing the cable from the sheave. Turning the grooves to the same size and diameter does not completely remove the trouble. Owing to the cables being of unequal diameters, on V-groove sheaves the smaller cables will go down deepest in the grooves and there will be a differential wear between the cables and grooves. Therefore, when the grooves are trued up the cables should be renewed.

With the fiber-packed sheave as with other types trouble is experienced with the grooves wearing so that the ropes run on

Fig. 269.—Tool for correcting unequal wear in fiber-packed sheave.

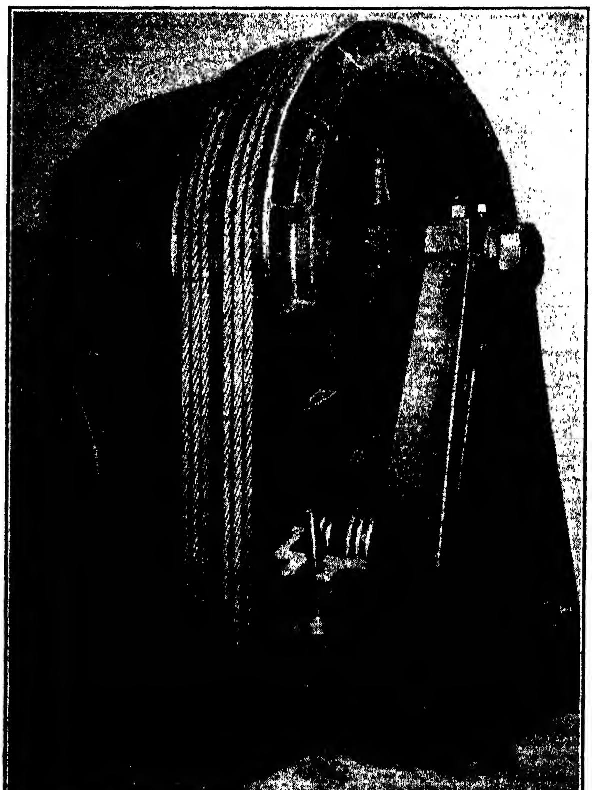


Fig. 270.—Tool shown in place at *A* to correct groove wear in traction sheave.

unequal diameters. The Neenan Elevator Corp., manufacturer of the fiber-packed sheave, has developed a device, Fig. 269, for bringing the grooves in these sheaves to the same diameter. This tool has integral rollers *R*, the number of rollers corresponding to the grooves in the sheave. These rollers are supported in a yoke that is hinged at *H* and can be raised and lowered by the adjustment screw *S*. To equalize the diameter of the grooves, the tool is placed under the sheave, as indicated at *A* in Fig. 270, and properly lined up, after which the rollers are pressed up into the grooves by the adjusting screw, while the elevator is in operation. The large-diameter grooves will come in contact with the rollers first and will be pressed to the same diameter as the smaller-diameter grooves, thus removing the groove differential from the sheave.

Renewing of the Cables.—The cables on an elevator do not generally give any trouble, but they should be renewed periodically before their condition becomes unsafe. This is generally done when six or more broken wires are found in one lay of any one strand. The cables should be inspected where they are attached to the sockets as well as in the main body of the cables. It not infrequently occurs that very few broken wires will occur in the main body of the cable, but a number will be found broken at the sockets. The size of sheaves, lubrication of cables, size of cables and the material from which they are constructed, number of strands and wires per strand, etc., are questions that offer a broad field of discussion that is outside the scope of this chapter.

Noisy operation of the car is generally due to worn guide bearings, lack of lubrication on the guide rails or the guide rails rough or out of line. The first two are the chief causes of noise. It sometimes occurs that when the safeties are set, they scar the guide rails at the point of application. These spots should be cleaned up with a file when the safeties are released.

As has already been mentioned, the mechanical faults that may develop in an elevator machine will vary somewhat with the type of equipment. But the foregoing will act as a guide to the most common defects. In most cases the mechanical defects that develop on elevators are quite obvious to a good mechanic, which is not always the case with the electrical troubles. Although the mechanical troubles do not vary widely on the different classes of machines, there is a great difference in the electrical faults that may develop.

CHAPTER XX

LOCATING FAULTS IN DIRECT-CURRENT MOTORS AND CONTROLLERS

Classification of Faults.—Faults in electric elevators may be divided into four classes: 1. Power supply. 2. Motor. 3. Control equipment. 4. Mechanical. On account of the wide variation in the power supply, types of motors, and controllers and the design of mechanical details, an almost infinite number of troubles can occur in elevator equipment.

The foregoing should not be understood to mean that electric elevators, when properly designed, installed and maintained, give any more trouble than any other similar type of apparatus. The truth of this statement is found in the fact that when we get on an elevator to be conveyed to a certain floor in a building, we are pretty sure of having our desires satisfactorily complied with, without any delay due to failure of the equipment. When the wide variety of control is considered, which ranges from a simple main-line and reversing switch on some of the older types of alternating-current equipment to a signal-control installation on modern equipment where the control of a high-speed elevator is entirely automatic, it is obvious that a wide variety of troubles can develop. This is so much so that the best that can be done in this chapter is to indicate in a general way how to go about locating the cause of trouble when it does occur.

Faults Due to the Power Supply.—If satisfactory operation of an elevator is to be expected, the power supply must be correct for the motor and control equipment. If the voltage is low on a direct-current system, it will cause the motor to fail to come up to full speed and may even cause the controller to function improperly. On the other hand, if the voltage is too high it will cause the speed of the motor to be above normal and may cause heating of the field and magnet coils. However, the latter is not very likely on account of the intermittent service. In any case if the elevator service is to be satisfactory the power supply must be up to par. In direct-current work the power supply is less liable to

be a factor in elevator operation than with alternating-current equipment.

Motor Troubles.—Direct-current motors used in elevator service are of the shunt or compound types, with or without interpoles. On direct-traction elevator machines, Fig. 271, the shunt-type motor is generally used and operates at speeds around 60 to 70 r.p.m. On geared-type traction machine, Fig. 272, and

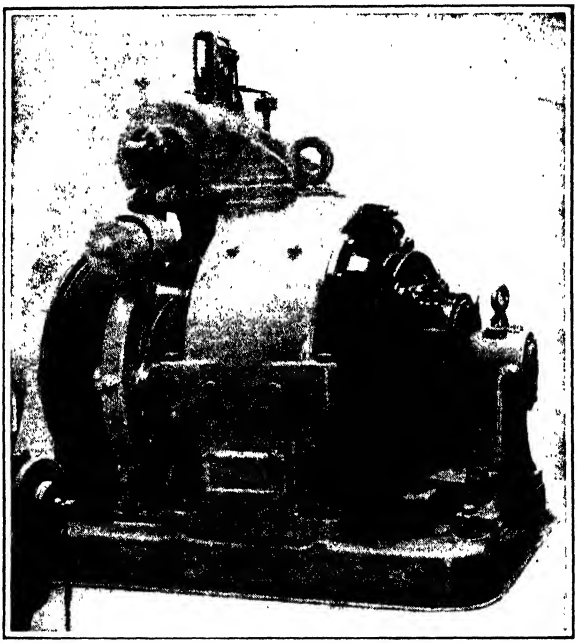


Fig. 271.—Direct-traction elevator machine.

the drum type, Fig. 275, compound motors operating at a comparatively high speed are used.

As elevator motors, in their general design, are not different from those found in other industrial services, they are subjected to about the same trouble. In direct-current motors these troubles may be divided into, sparking at the brushes, heating, excessive speed, speed too low, noise and failure to start. With some of the earlier types of motors that were not designed for reversing service, it was not possible to locate the brushes in a position to give sparkless operation on the commutator, on account of this position being back of the neutral for any given

direction. For reversing service the brushes of the motor must be set on the neutral. With modern types of machines, if other features of operation are correct, the motor will operate sparkless with the brushes on the neutral. Where interpole motors are used, it is necessary to check the position of the brushes carefully.

On account of the frequent starting and stopping the controller must be adjusted so as not to accelerate the motor too rapidly or sparking may result each time the motor is started, which will gradually make the commutator rough and eventually lead to trouble at the brushes. On modern elevator controllers the

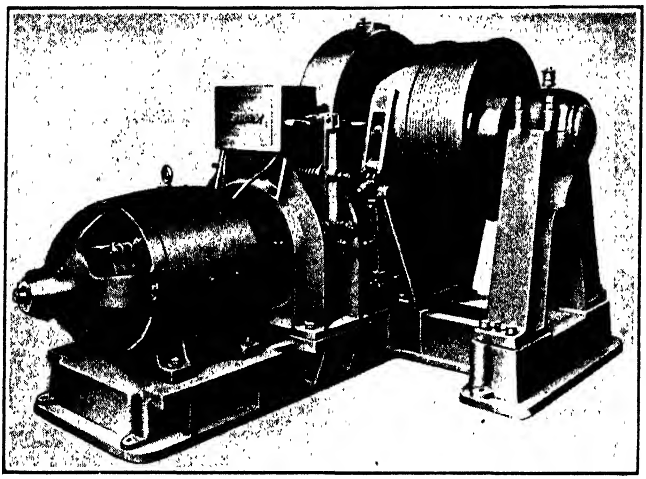


Fig. 272.—Heavy-duty geared traction elevator machine with two brakes, one being on the traction sheave.

motor armature is generally short-circuited through a resistance during the stopping period. This causes the motor to act as a generator and develops a braking action that assists the mechanical brake to bring the elevator to rest. If the resistance to which the armature is connected is made of too low a value, the current will be excessive and cause sparking at the brushes during the stopping period. Although this sparking is for only short periods, it will gradually roughen the commutator and cause sparking at the brushes during the full operating period. On most modern elevators it will be found that the discomfort to the passengers in the car will dictate how quickly the elevator can be started and stopped rather than commutation limitations.

In addition to the two conditions that are peculiar to elevator service, there are the faults that cause sparking at the brushes, which are common to almost all direct-current motors, namely: Brushes not set diametrically opposite; brushes not in line with the commutator bars; brushes not in good contact with the commutator, due either to dirt and oil on the brushes or to the condition of the commutator; high mica in the commutator; open-circuits in the armature; short-circuits in the armature; short-circuits in the field coils; wrong polarity of field coils.

Heating of the motor in elevator service is not so likely to occur as in industrial applications where the load may be increased to overload the motor. It is seldom, if ever, that an elevator motor is overloaded long enough to cause serious heating. The brake even if it were adjusted to cause overloading of the motor, would become so hot as to call attention to the condition before the motor would be injured. The chief causes of overheating of an elevator motor are: Short-circuits in the armature or the field coils; moisture in the windings; the windings becoming oil soaked, or the bearings worn so as to allow the armature to rub on the polepieces.

On account of the nature of the load it is seldom that trouble is experienced on the motor with hot bearings if they are kept properly lubricated with a good grade of oil. On geared-type machines with disk-type thrust bearings it is possible that these bearings may wear sufficiently to allow the thrust of the worm-shaft to be taken on one of the motor bearings, in which case heating of this bearing is likely to develop.

Excessive Speed.—Excessive speed will generally be found to be due to the series-field winding not being cut out of circuit after the motor comes up to speed. In elevator applications the motor may do service as a motor or generator. When the car and its load, in the up motion, are heavier than the counterweights, then the motor has to develop an effort to assist in raising the car and its load. In the down direction, if the car and its load are heavier than the counterweights, there will be a tendency to overspeed the motor, in which case the counter-electro-motive force in the armature becomes greater than the applied voltage and the motor becomes a generator and supplies a current into the power system, under which condition the motor acts as a brake to prevent over-speeding. When this change is made from motor to generator with a compound machine, if the relation between

the series- and shunt-field winding is correct for the motor, they will be wrong for generator operation. This will be understood by referring to Figs. 273 and 274.

In Fig. 273 the diagram shows the direction of the current through a compound machine as a motor. In this diagram the current in the series- and that in the shunt-field coils are in the same direction, which is correct. In Fig. 274 it is assumed that the motor's speed has been increased, by the elevator car in the down direction, to where it has become a generator and is pumping back into the power system. In this case the direction of the current in the armature and series-field winding is reversed. This gives the series- and shunt-field windings opposite polarity and weakens the field and would tend to reduce the braking

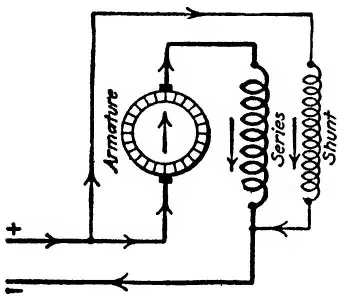


FIG. 273.

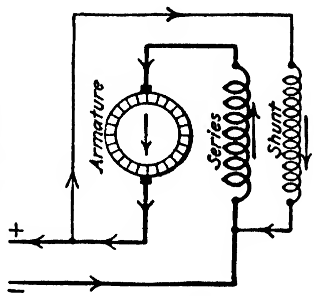


FIG. 274.

FIGS. 273 and 274.—Diagrams of compound motor.

FIG. 273.—Shows direction of current when the machine is operating as a motor. FIG. 274.—Shows direction of current when the machine has been converted into a generator.

current and let the elevator increase in speed. To overcome this difficulty, the controller is so arranged that the series-field winding is only in circuit while the motor is coming up to speed, after which it is cut out of circuit and the motor operates as a shunt machine. Should the controller fail to function so as to cut out the series winding, the motor will overspeed with a heavy load in the car in the down motion. It may also overspeed in the up motion with no load in the car on account of the over counterweight.

A case in mind of overspeeding of an elevator is that where the series-field winding of the motor was cut out in two steps. When the motor was connected up, a mistake was made and one section of the series winding was connected in so that it had the wrong

polarity. This left the series winding so that it was practically ineffective during starting, since the effect of one section neutralized that of the other. As it happened the section connected correctly was cut out first and the section connected in wrong was cut out last. One day the elevator started to overspeed in the up direction and then the wrong connection of the series-field coils was discovered. The cause of the overspeeding was found to be due to the controller functioning so that only half of the series-field winding was cut out. As the section of the series winding in circuit was connected wrong, the motor was running with one-half of the series winding opposing the shunt winding, which weakened the field and increased the motor's speed.

In the down direction with a heavy load in the car, if the armature resistance is not cut out of circuit, there will be a tendency to overspeed. On account of the added resistance in the armature circuit, the motor operating as a generator has to run at an increased speed to set up the necessary braking current to arrest the motion of the car. On some of the old hand-rope controlled elevators, it was possible for the operator to release the brake without connecting the motor and controller into circuit. Under such a condition the elevator would be likely to overspeed if released with a load in the car.

Open-circuits or short-circuits in the shunt-field windings will also cause excessive speed, but the conditions will generally cause blowing of the fuses, when the series-field winding is cut out of circuit. One case in mind of an elevator with a hand-rope control, the shunt-field coils were open-circuited, but the operator manipulated the control so as not to cut out the series winding and ran the elevator with the motor operating as a series machine. Needless to say, the machine operated at an excessive speed.

Shifting the brushes back of the neutral will cause an increase in speed. On a reversing motor, if the brushes are back of the neutral for one direction of rotation, they will be ahead of the neutral in the other direction of rotation. Therefore if the brushes are shifted accidentally or otherwise off the neutral of an elevator motor, it will result in increased speed in one direction of motion of the car and reduced speed in the other. If the brushes are shifted very far, severe sparking will result, which may cause flashing over on the commutator and the fuses or circuit breaker to open.

Causes of Fuses Blowing.—Other faults in the motor that would cause the fuse to blow are: Short-circuit of a number of coils in the armature; open-circuits in the armature, where they produce sparking severe enough to cause flashing over on the commutator; open-circuit in the shunt-field coils; short-circuit between the shunt- and series-field coils; grounds in the field coils or armature windings. In some cases the brushes may start to chatter and cause a flashover on the commutator, resulting in the fuses blowing. On motors of 10- or 15-hp. rating such a flashover may not leave much of an indication on the commutator of what happened. If such occurrences are only intermittent and no one happens to be near the machine when the flashover occurs, the cause of the fuses blowing may be difficult to locate. In one case a 10-hp. 220-volt motor had been blowing the fuse at irregular intervals of a few days for several months before the cause, flashing over on the commutator, was discovered. In no case was a mark left on the commutator or brushes and holders that would indicate that the fault was in this part of the machine. The fault was located by a guess on the part of the maintenance man, that when the armature rotated against the brushes, they might at times chatter and cause a flashover. A little experimenting soon showed that this did happen, and the cause was eliminated by properly adjusting the brushes.

Another cause of the fuses blowing, is the series- and shunt-field windings connected so as to have wrong polarity. On account of the comparatively large number of turns used in the series winding of compound motors for elevator service, it will generally be impossible to put the motor into service with the field coils in opposition without causing excessive speed or blowing the fuses. However, if trouble is being experienced with a compound elevator motor, it will be advisable to check up the polarity of the field coils. Short-circuit between the shunt- and series-field coils, grounds in the field coils or armature windings will cause the fuses to blow. Other causes of fuses blowing have to do with faults in the controller and mechanical parts of the equipment.

Speed Too Low.—Causes of the motor failing to come up to speed are usually due to the controller failing to function properly, such as not cutting out the starting resistance, brake not releasing, etc., and will be discussed later in this chapter. The armature rubbing on the polepieces, due either to worn bearings or to a

loose polepiece, would cause a reduction in speed. A short-circuit of a number of coils in the armature is also another cause of the motor failing to come up to speed. Any of these causes will generally be accompanied by excessive heating.

Noisy Operation of the Motor.—Noisy operation of the motor is generally due to mechanical faults such as the motor not in line with the wormshaft, armature out of balance, loose parts, armature striking the polepieces, rough commutator or chattering of the brushes. A common cause of noisy operation is the motor out of line with the wormshaft. It is necessary that the motor be carefully lined up, not alone to eliminate noisy operation, but also to prevent breaking the armature shaft at the brake-wheel coupling. In alternating-current motors conditions in the power system affect the quietness of the motor's operation, see Chapter XXI.

Locating Troubles in Controllers.—Troubles that may occur on elevator controllers are almost limitless in their form. On the simpler types of controllers, faults when they do occur can generally be located by those with a limited electrical knowledge. In the more complicated equipment the location of the cause of faulty operation may require the services of an experienced elevator engineer. A diagram of the controller and motor connections is not necessary, but may be of material assistance in locating a fault. Some of the most successful trouble shooters have been those who paid little heed to diagrams, but depended upon a thorough knowledge of fundamental principles.

If the electrical equipment of an elevator is causing trouble, its action will give the trained trouble man a good idea where the fault is. For example, assume that the motor fails to start. The first assumption in such a case would be that the fuses are blown or the power is off the system, and this is one of the first things that should be tested for. If the controller is of a type with a potential switch, if this switch remains closed it would indicate that the circuit was alive, since the potential switch remains closed only as long as power is on the line and the emergency limits are closed.

Where the fuses are found blown, they should be replaced and an investigation made as to the cause. An inspection should be made to see that all contactors on the controller are in their normal off position and that they are in good operating condition. A check should be made of the brush position on the motor and

to see that the brush yoke is locked in position. If the motor and controller are found in good condition, a test should be made for grounds. When making this test, not only the motor, but also all terminals on the control board, should be tested.

Test the Shunt-field Winding of the Motor.—After testing for grounds and finding the motor and control clear, it will be advisable to test the shunt-field circuit to see that this is complete. The method of making such a test will depend on how the field winding is connected to the line. If the shunt-field winding is connected directly to the line, as in many types of controllers, then closing the line and potential switch will energize the field winding. In this case, if the field circuit is complete, an arc will be obtained at the line switch when it is opened, and the field poles will have a strong attraction for a screwdriver or a pair of pliers if placed against them when the coils are energized. When the field coils are energized and the circuit is interrupted, a high voltage is induced in the coils similar to that in a spark coil. If this circuit is interrupted too quickly, there is danger of the voltage being high enough to cause insulation failures. Therefore, if the line switch is opened, it should be done slowly so as not to interrupt the field circuit too quickly and subject the insulation on the motor to unnecessarily high voltage strains.

On some types of controllers the shunt-field winding is disconnected from the line with the rest of the motor, every time the elevator is stopped. In these cases a test of the field winding can be made by opening one side of the armature circuit, then closing the line and potential switches and throwing the control in the car to either the up or the down position. This will allow the controller to function and energize the field coils with the armature circuit dead. Indications of the field circuit being complete are as have been previously mentioned. In making either one of these field tests, the current in the field coils can be limited by connecting a lamp in series with them, and if the circuit is complete the lamp will light.

After the foregoing tests have been made on the motor and controller and no cause of the fuses blowing can be found, or if a cause has been found and removed, the line and potential switches may be closed and the elevator started from the car switch. If the elevator runs all right, it should be watched for a few trips to see if anything irregular develops in the control.

Precautions to Take before Starting the Elevator.—Before starting the elevator, it will be well to block the accelerating switch open so that the starting resistance cannot be cut out. In this way a test can be made for an open-circuit in the starting resistance. With the accelerating switch blocked in the off position the motor should start, if the starting resistance and the rest of the armature circuit are completed. If the motor does not start, an investigation should be made for the cause. In some types of controller, such as those employing the counter-electromotive-force principle, the accelerating switch may not function

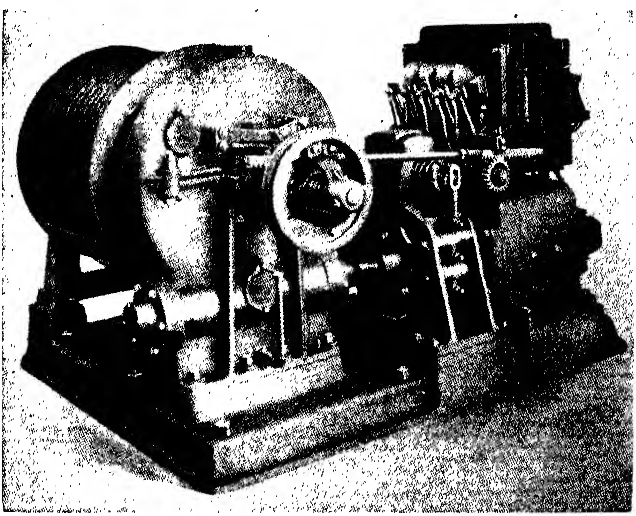


Fig. 275.—Drum-type mechanically controlled elevator.

when the starting resistance is open-circuited, depending on where the fault is in the resistance and how the magnet coil is connected. The time-limit type of controller will function and cut the resistance out whether there is an open-circuit in this resistance or not. If the starting resistance is open-circuited and part of it is cut out before the motor circuit is completed, the inrush current is likely to be high enough to blow the fuses.

Particular attention should be given to the motor when first started, to see if it functions properly. A short-circuit of a group of armature coils will prevent the motor from coming up to speed. The motor will act as though it were heavily loaded and will heat, particularly the short-circuited coils.

When starting with the accelerating switch blocked open, the motor and starting resistance should be carefully watched to see that there is nothing wrong with the former that might cause the latter to overheat. For example, a short-circuit in a group of coils in the armature would cause it to take a heavy current through the starting resistance and cause this resistance to heat excessively.

The brake should also be watched to see that it releases properly. After the motor is found to operate properly with the

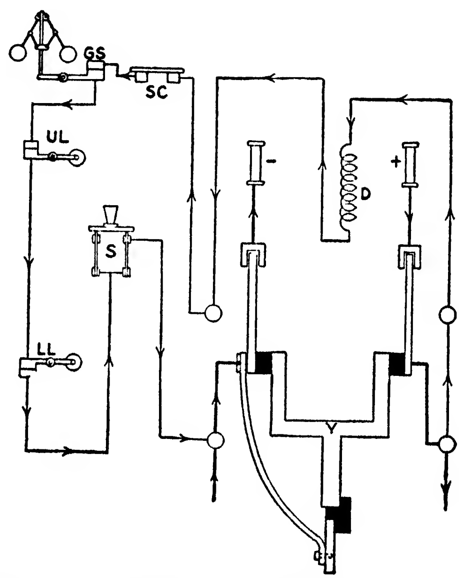


FIG. 276.—Diagrams of potential-switch holding-coil circuit for medium-speed elevator.

starting resistance in circuit, the accelerating switch should be released and the elevator brought up to full speed, all the time watching the motor and control for any irregularities.

Causes of the Potential Switch Not Staying Closed.—Assume a condition where the fuses are found to be all right, but the potential switch will not remain closed. This would indicate an open in the holding-coil circuit of this switch. Various protective devices are connected in series with the coil on the potential switch. On a simple hand-rope controlled drum-type machine, Fig. 275, these may consist, as shown in Fig. 276, of a slack-cable

switch *SC*, governor switch *GS*, upper hatchway-limit switch *UL*, lower hatchway-limit switch *LL*, safety switch *S* in the car, and on some machines a final drum-shaft limit switch. The opening of any of these devices will de-energize holding coil *D* and allow the potential switch to open.

For example, if the car were to come down on the bumpers and the cables became slack, the potential-switch coil circuit would be opened by the slack-cable switch and also by the lower hatchway-limit switch. It would, in such a case, be necessary to take up the slack in the cable on the drum and raise the car off the lower hatchway-limit switch before the potential switch will remain closed.

After the machine has been moved by hand until the slack is taken out of the cables, the car can be raised by holding the potential switch closed and operating the machine from the car switch or closing the up-motion switch on the controller by hand. Care must be exercised in doing this, as a mistake may cause the counterweights to be pulled into the overhead work with disastrous results.

Car or Counterweights Landed.—When the car or counterweights are bottomed and the cables are slack on the drum, it is not advisable to try moving the machine with the motor, as there is danger of getting the cables crossed and also subjecting them to heavy strains. With the car cables slack the total weight of the drum counterweight is effective in turning the drum. If the brake is released and the machine started by the motor, before the brake can be applied again, the slack is likely to be taken out of the cables more quickly than is good for the equipment.

If an attempt is to be made to move the machine by the motor, open the brake coil circuit so that the brake cannot be released and then close the up-direction switch by hand at the control board, if the car is bottomed. In this case the brake remains applied at all times; if the motor moves the machinery, it will be very slowly and just as quickly as the power is cut out of the motor the machine will stop.

The same operation can generally be done to better advantage by using a spanner wrench on the brake-wheel coupling. Where this cannot be done, an iron bar can generally be used in the brake wheel as a lever to turn it in the desired direction. This turning can usually be done without releasing the brake. On some machines the motor shaft is extended beyond the outboard

bearing, with a square end to allow the use of a wrench for moving the machine by hand.

On elevators having brakes applied by a weight on a lever, one man on the brake lever to control the motion of the car and another to turn the brake wheel by hand make for safety in taking slack out of the cables. Where the motor shaft is extended for using a wrench to move the machine by hand, it is not advisable to use a Stilson wrench, since after the machine is started it may be necessary to apply effort to the wrench in the reverse direction to control the speed of the machine. In this case there is danger of the wrench opening sufficiently to lose hold on the shaft. The manufacturers generally furnish a socket wrench to go on the end of the motor shaft, but unfortunately it is one of those things that is seldom preserved for the purpose for which it was intended and is very likely not to be available when needed.

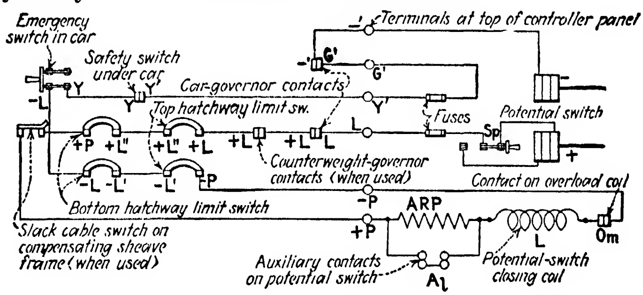


FIG. 277.—Diagrams of potential-switch closing-coil circuit for high-speed traction elevator.

Potential-switch Coil Circuit on High-speed Elevators.—On high-speed traction elevators the potential-switch circuit becomes somewhat more involved than with the drum-type machine or the slow- and medium-speed traction machines. Figure 277 shows the potential switch circuit of an Otis type *MFL4C* controller, Fig. 278, for high-speed traction elevators. Starting from the + side of the line the circuit is through the single-pole switch S_p and a fuse on the control board. From the control board the circuit goes through contacts L on the car-governor switch, then through contact $+L$ on the counterweight governor, contact $+L''$ on the top hatchway-limit switch, contact $+P$ on the bottom hatchway-limit switch, slack-cable switch on the compensating-sheave frame at the bottom of the hatchway, then back to the control board and through coil L of the potential switch. When the

switch is open, contacts A_l are closed and resistance ARP is cut out of circuit with coil L so that when the coil is energized it can close the switch. Closing the potential switch opens contacts A_l and cuts resistance ARP in series with coil L and reduces the current through the coil.

From the control board the circuit continues through contact O_m on the overload relay, contact $-P$ on the top hatchway-limit switch, $-$L on the bottom hatchway-limit switch, one side of the emergency switch Y in the car and safety Y' under the car. The last-named switch is mounted on the car safety plank and is opened in case the governor applies the safeties and stops the car in case of overspeed. From the car safety switch, the circuit is back to the control board through a fuse and to contact G' on the car-governor switch and then back to the $-$ main contact of the potential switch on the control board.

The opening of any of these devices in the potential-switch circuit will cause it to open and remain open as long as the auxiliary switches are open. Limit switches, located in the elevator hatchway or under the car, are subjected to dirt, grease and moisture in varying degrees, therefore their contacts should be given careful attention and kept clean, to prevent grounds and short-circuits and also to keep dirt from working into the contacts, interrupting the potential-switch coil circuit and shutting the elevator down.

Locating Cause of Potential Switch Not Remaining Closed.—In case the potential switch will not remain closed, and it has been ascertained that the line is alive, all the devices in circuit with the closing coil should be carefully examined and cleaned to make sure that they are closed and making contact. This should be done after testing the fuses in the circuit to determine if they are complete. If the fault is not found in any of these auxiliary switches, then the circuit through the coil should be tested to see that it is not open. After this has been done and the coil found in good condition, it will then be a case of testing the wiring. The most likely place to find an open in the wiring is in the traveling cable from the junction box, located halfway up the hatchway, to the car.

An open-circuit in a wire of the traveling cable may be difficult to locate, since owing to the bending of the cable the wire may be open-circuited at one location of the car and at another position it may be closed, or a wire may be open and a slight movement of

the cable will cause it to close. If trouble is being experienced with an intermittent open in the potential-switch circuit—that is, the potential switch will not remain closed at times and at others it will—this is a pretty safe indication that the fault is in the traveling cable and it should be renewed.

One case in mind is that where an open-circuit had been occurring in a potential-switch coil circuit, at intervals ranging from a day to a week, but always before the fault could be found the circuit would close again and the elevator would operate for another period when the trouble would occur. This had been going on for about six months before it was decided to renew the traveling cable. After installation of the new cable no more trouble was experienced with the potential switch opening unexpectedly.

Where trouble of this kind is being experienced, if the car is run up the hatchway to just above the control-circuit junction box in the hatchway, the traveling cable can be pulled out on the floor. Then with the potential switch closed, begin at one end of the cable and gradually work along it and at the same time bend the cable back and forth. In this way the broken wire will probably be opened and the potential switch will open. A man should be stationed at the control board to note when this happens. If the fault in the cable can be located, it can be repaired, but this is generally not a course to be recommended, except as a temporary measure, since the old cable is in such condition that trouble is likely to develop in a short time at another place.

The governor out of adjustment or too quick acceleration of the car may cause the governor to open its switch without setting the safeties, and open the potential switch. On some types of machines the governor switch is opened only when the safeties are set, in which case the foregoing cannot occur without setting the safeties on the car.

In Fig. 278 switch S_p has two positions. When closed to the right as in the figure, the potential switch will close when its coil circuit is energized. With switch S_p thrown to the left the connections on the controller are such that the potential switch must be closed by hand, after which it will remain closed if the coil circuit is energized. These two arrangements will cause different effects if resistance *ARP*, in series with the potential switch coil L, is open.

When the potential switch is open, contacts A_1, Fig. 277, are closed and short-circuit resistance *ARP* so that when switch S_p

is closed to the right the potential switch will start to close. If there is an open in resistance *ARP*, then as soon as the contacts A_1 open, the circuit through the coil will be broken and the switch will open, only to close contacts A_1 and energize the closing coil, which will cause the switch to start closing again. This operation will keep up until the main line switch is opened and the

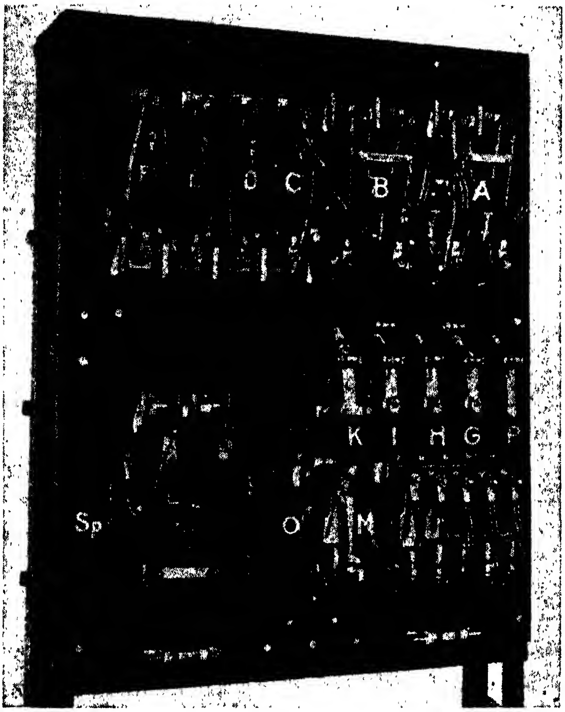


FIG. 278.—Controller for high-speed traction elevator.

The different switches are: *L*, potential switch; *A* and *B*, direction switches; *M*, accelerating magnet; *C*, *D*, and *F*, high-speed switches *G* and *I*, non-reversal magnets; *H*, auxiliary-load magnet; *K*, field-resistance magnet; *O*, auxiliary brake magnet; *P*, auxiliary brake-resistance magnet; and *Sp*, knife switch in potential-switch closing-coil circuit.

power cut off the control board. It is evident that continuous opening and closing action of the potential switch would indicate that the resistance in series with the closing coil is open-circuited. Such an action of any magnet switch would indicate that the resistance in series with it is open-circuited. If the switch S_p is thrown to the left, the potential switch will remain closed only after closing by hand, and the coil circuit is energized. In this

case, with resistance *ARP* open, the potential switch will not remain closed, just as when there is an open in any other part of the circuit.

About the same effect would be obtained if part of the turns in coil *L* were short-circuited, as with an open-circuit in resistance *ARP*. When the potential switch is open, the current through its coil may be great enough to cause the switch to close. When it does close, resistance *ARP* is cut into circuit and may reduce the current to a value that will not hold the switch closed, on account of part of the turns being cut out of the coil. With an open-circuit in resistance *ARP*, when the switch closes a vicious arc should occur at contacts A_1, which would not occur with a short-circuit in the coil or if conditions in the circuit were normal. With an open-circuit in resistance *ARP* the arcing of contacts A_1 may hold over and the switch stay closed. If a short-circuit is in the coil, resistance *ARP* will get unduly hot if the switch remains closed.

It is possible for loose or poor connections to introduce resistance enough in the circuit to prevent the potential switch from closing or remaining closed after being closed. If there is a suspicion that the trouble is in the potential-switch coil and resistance, disconnecting these from the rest of the circuit and connecting them directly across the line will show how they are functioning. If improper operation is obtained under these conditions, it will be known that the fault is in the closing coil or the resistance or both.

The foregoing indicates in a general way what may cause the main fuse to blow or the potential switch to remain open. These conditions will vary widely with different types of controllers. On some equipments the potential switch coils are in series with the direction switch coils, so that the potential switch opens and closes with the direction switches. In such a connection most anything that would affect the closing of the potential switches will also affect the direction switches.

Testing the Direction Switches.—After it has been ascertained that conditions in the power circuit are correct for operating the elevator motor and controller, as previously described, and the motor fails to start, then attention should be given to the other circuits. On elevators that are operated from a hand rope or a wheel in the car, the direction switches are usually of a mechanical form, such as a cylindrical type, Fig. 279, or a type closed and

opened by cams on a shaft operated from the shipper wheel, shown on the right, Fig. 280; or any of numerous other devices that are employed. These switches, being of the mechanical type, are positive in their action and should close when the control mechanism is thrown to either the up or down direction.

Assume that it has been found that the power circuit is complete and alive to the controller, and the motor fails to start when the reverse switch is closed. There are two conditions, one where the motor will not start with the switch closed for one direction and will start with the reverse switch closed for the other direction. Such a condition would indicate that the trouble was in the

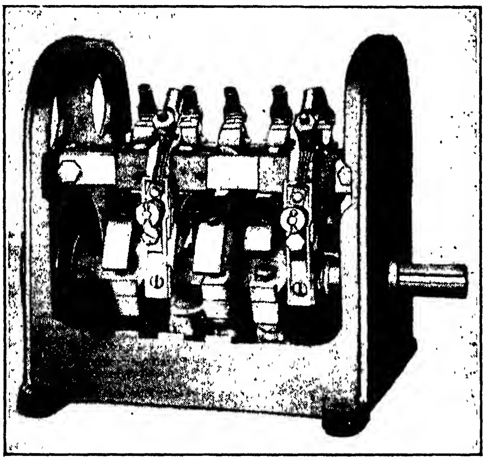


Fig. 279.—Cylindrical-type reversing switch.

reverse switch, which, when closed, the motor failed to start. This confines the search for the trouble to a small part of the equipment. In such cases it will generally be found that the contacts on the switch have become worn or are out of adjustment and do not touch so as to make the circuit. It is also possible that the contacts have become broken or otherwise made inoperative, or their connections may be loose or broken.

To make an inspection of the reversing switch, open the line switch and pull the control to the position in which the motor failed to start. In this way it can be readily seen how the contacts fit and loose or broken connections can be looked for at the same time.

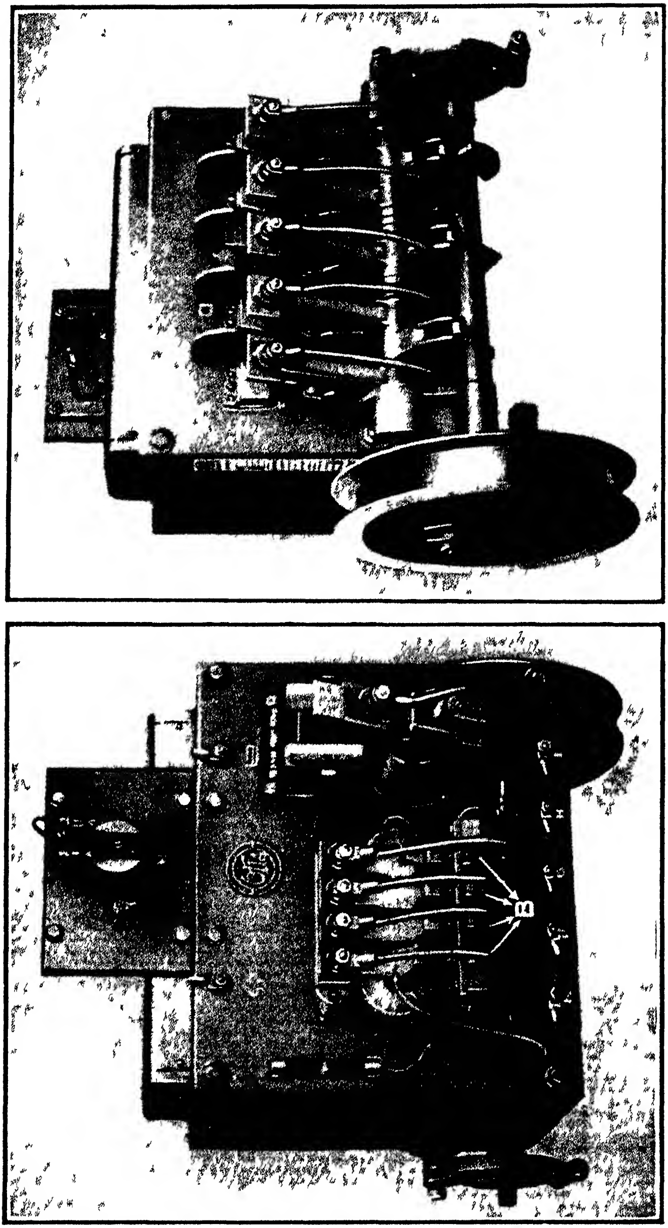


FIG 280.—Mechanical or semi-magnetic type controller for traction elevator.

The second condition is that where the motor fails to start with the reverse switch thrown for either direction. It is possible for the reverse switch to be out of order for one direction, but not very likely for both directions at the same time. Therefore, if the motor fails to respond with the reverse .switches in either direction, it is a pretty good indication that the cause of the trouble is somewhere else than in the switches. The first thing to observe is that the switches function properly, as this will show whether the fault is in the mechanical operating mechanism or in the electric circuits.

Assume that the direction switches have been found to function properly, then the source of the fault may be assumed to be in the

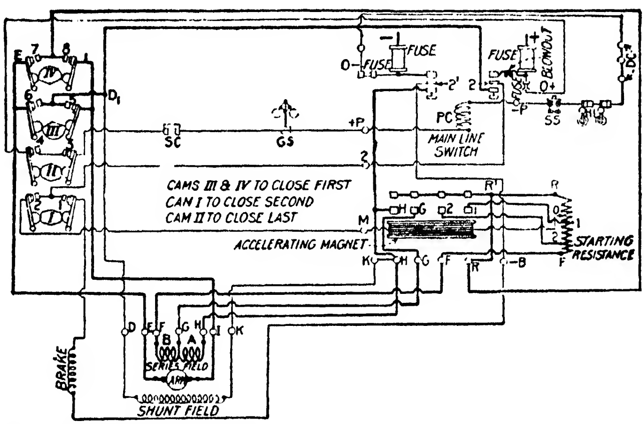


FIG. 281.—Diagram of an Otis semi-magnetic type controller for drum-type elevators.

motor-circuit wiring. To make sure that the power circuit is complete to the controller, it is well to make a test across the first two line terminals in the controller. For example, in Fig. 281 the + side of the main line or potential switch *PC* is connected to 5 on the direction switches, and the − side is connected to *II* on the controller. If a lamp is connected from 5 to *H* and the potential switch closed, the lamp should light. Failure of the lamp to light would indicate that something was wrong in the power circuit before it actually reached the controller.

Where only one terminal can be found on the controller, one lamp lead can be connected to this and with the other test on the part of the controller to which the opposite side of the power cir-

cuit leads. For example, in Fig. 281 only terminal H is on the controller, 5 being on the reverse switches located on the end of the drum shaft as at A in Fig. 282. In this case one lead of the test lamp can be connected to H terminal on the controller and with the other lead test on the reverse switch located over the end of the drum shaft. If the circuit is complete, a light should be obtained. If the lamp does not light, this places the location of the fault somewhere between where the test was made and the power supply.

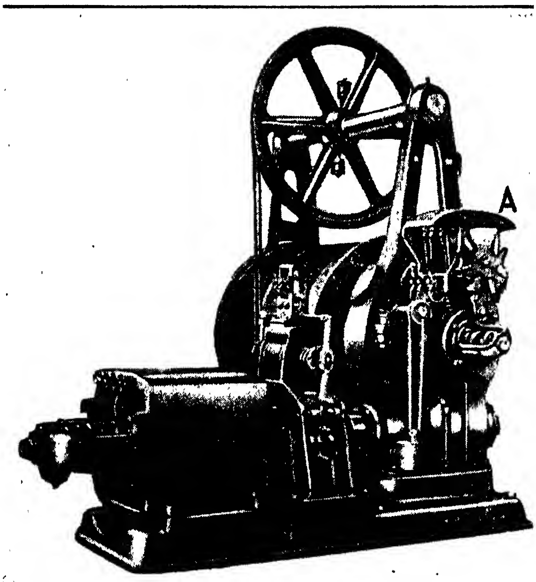


FIG. 282.—Drum-type elevator machine.

Open-circuit in the Starting Resistance.—Where the test shows that the circuit is alive to the controller and the motor will not start with the reverse switch in either position, then the most likely place to find the fault is in the motor or starting resistance, although it is possible for the fault to be in any part of the armature circuit. The starting resistance and series field may be tested by connecting a lamp in series with the armature, then close the line switch and then the accelerating switch by hand. Closing the accelerating switch cuts out the starting resistance and series-field winding, therefore the lamp should light if the

armature circuit is complete. In this way the source of the trouble will be segregated and can be easily located.

With a time-limit type of controller—that is, where the time of cutting out the starting resistance is controlled by a dash pot, as in Fig. 283—the starting resistance will be cut out of circuit whether the motor circuit is complete or not. With such a controller if the starting resistance or series-field winding opens, the accelerating switch will function to cut out the starting resistance, but the motor does not start. When the arm on the accelerating switch moves by the contacts to which the open section

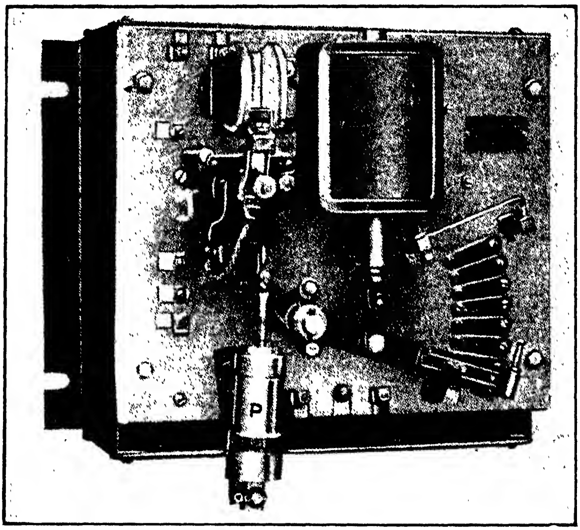


Fig. 283.—Time-limit type controller.

of the resistance is connected, the motor armature circuit will be completed. On account of part of the starting resistance or the series winding being cut out of circuit, the inrush current will probably be sufficient blow the fuses and cause burning at the contacts where the open is in the motor circuit, clearly indicating the source of the trouble.

On some machines with mechanical type controls the motor circuit goes through an ultimate limit switch that is opened by the drum-shaft limits when the car goes by the terminal landings. These switches have been known to open accidentally, so that when the motor fails to start it should be ascertained if such a

limit switch is part of the control equipment and if so, is it in the closed position?

Motor Fails to Start When Power Circuit is Complete.—The foregoing discussion is based on the premise that when the direction switches were closed, the motor did not start and when they were opened, no arc was obtained at the contacts. It is possible to have the motor fail to start and obtain a heavy arc at the switch contacts when they are opened. This would indicate that current was passing through the motor, but owing to some fault it could not start. This could be caused by the wormshaft jamming in the thrust bearings, the motor bearings worn to allow the armature to rub on the polepieces, or the motor bearings set on the armature shaft. These things have happened, but they are of rather rare occurrence.

Test for such faults would be to open the brake and see if the armature and wormshaft and other moving parts of the equipment move freely. If there is no load in the car, the armature and wormshaft should turn freely in the direction that will raise the car, as the counterweight is generally the heavier of the two.

A more likely cause of the motor not starting properly is a short-circuit in a group of coils in the armature. In this case the armature will generally start, but will not come up to full speed, but turn slowly and act as if heavily loaded. This will cause heating of the armature coils and the starting resistance and may blow the fuses if the controller is of a type that will cut out the starting resistence under overload conditions.

Another cause of the motor failing to start is the brushes shifted off the neutral, and their position should be checked.

Where power is supplied from a two-wire ungrounded system, if a ground occurred on the side of the line, going directly to the motor and also in the armature or series winding, the motor would not start and if part of the starting resistance is cut out the fuses would blow. If the ground is on the side of the line in which the starting resistance is connected, the fuse will blow as soon as the reversing switch is closed. On a three-wire system with a grounded neutral the fuse would blow whenever a ground occurred in the armature circuit of the motor, operating on the full voltage of the system, when the reverse switch is closed. Combinations of grounds in the motor and controller have been known to allow the elevator to operate in one direction and blow the fuses when the reverse switch was thrown to the other direction.

Testing the Shunt-field Winding.—With an open in the shunt-field circuit, the motor will generally start if it is not too heavily loaded, but the fuses will blow if the starting resistance and series-field winding are cut out of circuit. Test can be made for an open in the shunt-field-coil circuit by opening the armature circuit and pulling the controller to the on position. For example, in Fig. 281 the armature leads can be disconnected at *I* or *E*. When doing this, precautions should be taken to prevent the loose lead-making contact with some other part of the motor and causing a short-circuit when the controller is pulled to the on position.

The brushes may be insulated from the commutator with a piece of cardboard instead of disconnecting the armature leads. When doing this, care must be exercised to see that carbon and copper dust on the brushes does not form a conducting path from the brushes to the commutator and cause an arc that will damage the commutator when the switch is closed. When the controller is put in the on position with the armature circuit open, if the field coils are energized the polepieces will attract a screwdriver or any piece of iron that may be brought near them. When the switch is opened, an arc should be obtained at its contacts.

Brake Fails to Release.—Another cause that may prevent the motor from starting when the circuit is complete through it, is the brake not releasing. Where the brake is mechanically operated, it is not likely to fail to open. As the lining wears out of the brake shoes, adjustments are generally made to take up the increased clearance between the brake shoes and the pulley when the brake is released. When the old linings are replaced with new ones, the latter may be so thick that the operating mechanism cannot lift the shoes far enough to release the brake until it has been adjusted for the new linings.

Where the brake is operated electrically, there are a number of causes for its failing to release. First, the coil circuit may be open, which can be due to broken wires in some part of the circuit, or the contacts that open and close the circuit may be out of adjustment, worn so that they do not close, or they may be prevented from closing by dirt between them. If the circuit is complete, the cores may be so far out of the coil that the latter will not develop sufficient pull to release the brake. For example, in Fig. 284, the more the brake-shoe linings *B* wear the farther the cores *D′* will be pulled out of the coil *E* when the brake is applied,

and it is possible for them to be far enough apart to reduce the pull of the coil to where the brake will not release.

Adjustments are made by screwing the stems *D* in and out of the cores so that when the cores pull together the brake shoes will be just lifted clear of the brake wheel. As the brake lining wears, the stems *D* should be backed out of the cores to maintain the adjustment. If such an adjustment is maintained until the brake lining is worn to where it has to be renewed, when the new lining is put into the shoes it will probably be found that with the old

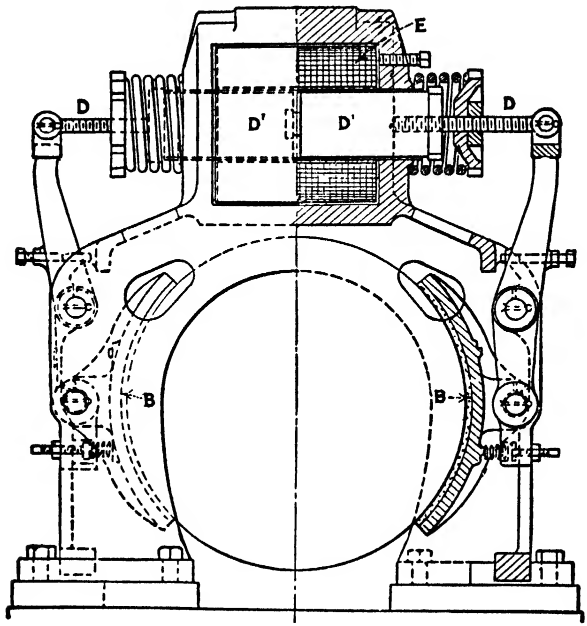


Fig. 284.—Magnet-type brake.

adjustment the core will touch when the brake shoes are in contact with the pulley. To correct this condition stems *D* will have to be screwed into cores *D′* to separate the latter far enough to give sufficient movement to lift the brake shoes clear of the pulley.

In one case the brake shoes were installed after they had been lined and no adjustment made so that the coil could lift the shoes. In this case the motor could operate the elevator when the brake was applied, with the result that the new brake linings were badly burned before it was discovered that the brake could not release.

On some brakes a resistance is connected in series with the brake coil and this resistance is short-circuited by contacts when the brake is applied. This allows the coil to be connected directly across the line to obtain a strong pull for releasing the brake. When the brake releases, the contacts short-circuiting the resistance open and cut the resistance in series with the brake coil. If these contacts get out of adjustment and do not close when the brake is applied, the resistance will remain in series with the coil and it cannot develop sufficient pull to lift the brake shoes.

On the other hand, if the resistance were open-circuited and the contacts closed, as they should when the brake is applied, this would cut the resistance out of circuit. When the brake coil is energized, it will start to release the brake, but when the resistance contacts part, the coil circuit will be opened and the brake released and then immediately applied again. In some cases the arc at the contacts, when they open, may hold across and the brake remain released. In such event the contacts will soon be burned so short that they will not meet when the brake is applied, and the coil circuit will then be opened through the resistance, and the coil cannot be energized to release the brake.

On some types of controllers compound brake coils are used. A shunt coil is connected across the line, as in Fig. 148, and in addition a series coil is connected in the armature circuit. This series coil is cut out of circuit with the series winding on the motor, so that it is used only to assist the shunt coil in releasing the brake. It is necessary that the coils have the same polarity or the effect of one will neutralize that of the other and the brake will not release. Once connected properly, the coils will remain so unless someone changes the connections. On other types of brakes they are equipped with a dashpot to control the operation of the brake. Through neglect the dashpot may get into such condition as to stick and prevent the coil from releasing the brake.

Failure of the Accelerating Switch to Function.—Failure of the accelerating switch to function and cut out the resistance will depend largely upon the principle on which this switch operates and how it is connected in the circuit. In any case an open-circuit through its coil or coils will prevent operation. This open-circuit may be due to an open in the wiring or loose connections, or the auxiliary contact that closes the coil circuit may be out of adjustment or making poor connection.

In the controller, Fig. 285, when the main-line switch M closes it completes the circuit for the accelerating-switch coil AC. The circuit is from the + side of the line through contact X, coil AC, resistance AB to the − side of the line. Resistance AB is short-circuited by a contact A'. If this resistance were open-circuited, it would not interfere with the coil raising the arm and cutting out the resistance until it reached near the end of its travel, when contact A' will open and in doing so open the coil circuit through resistance AB. In doing this, the coil releases the arm, which

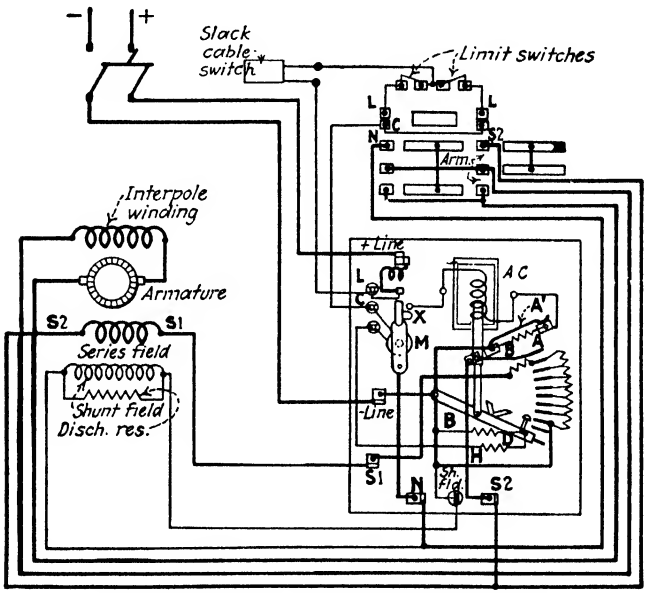


FIG. 285.—Diagram of the controller Fig. 283.

starts to drop down, allows contact A' to close and energizes coil AC, which will raise the arm again, open contact A' and the coil circuit. From this it will be seen that the arm oscillating up and down at the upper end of travel would indicate that the resistance, in series with the coil, is open-circuited. If contact A' did not short-circuit resistance AB, coil AC could not develop sufficient pull to raise the arm and cut out the starting resistance.

The coil circuit of main-line switch M is from the + side of the line to L through the slack-cable and limit switches back to C, through coil M, resistance H, starting-resistance arm and to the − side of the line. When coil AC raises its arm off the first con-

tact, resistance D is cut into circuit with coil M. If resistance D is open-circuited, coil M will be de-energized and allow its switch to open and cut the power out of the motor. The starting-resistance arm will drop to the off position and short-circuit resistance D out of circuit and again complete the circuit for coil M. This will start the motor again, only to have it stopped when the starting-resistance arm moves off the first contact. Where a switch has an oscillating movement, it is a pretty good indication that the resistance, connected in series with its coil, is open.

Where a dash pot is used to control the motion of a switch, unless given attention it is likely to give trouble, especially some of the earlier designs of dashpots. If subjected to extreme cold, dashpots are likely to be sluggish and stick, and at high temperatures they may operate too freely unless properly adjusted.

In some cases the starting-resistance arm has been known to stick in the up position and cause the fuse to blow when the direction switch is closed. Where the line contactor coil M is connected as in Fig. 285, the starting-resistance arm must return to the off position or the line switch will not close, on account of resistance D being connected in series with coil M.

On the controller, Fig. 281, the accelerating switch operates on the counter-electromotive-force principle. In this case the motor must start and build up a certain voltage across its terminal before sufficient current will flow in the coil to cause contactors 1, 2, G and H to close and short-circuit the starting resistance. If the motor is too heavily loaded, it may not be able to reach a speed where the contactors will close. Adjustments are made by screws B, Fig. 280, and when raised or lowered, the arms come closer or farther away from the magnet core. Adjustment can also be made by shifting point O, Fig. 281, where the coil connects into the starting resistance. Moving connection O toward F tends to make the contactors close at a lower speed on the motor and a given load, whereas moving O toward R has the opposite effect. When the elevator is installed, the proper location of O is made by the manufacturer and the only subsequent adjustment that may have to be made is of the contactors.

Methods of adjusting the accelerating switches vary with the type and make. If they are adjusted to accelerate the motor too quickly, it may result in blowing the fuse or impart an unpleasant motion to the car when starting.

Full-magnet Type Controllers.—On a full-magnet type elevator controller the limit and safety switches are divided between the potential-switch and direction-switch coil circuits. Figures 286 to 290 show some common arrangements of potential-switch and direction-switch circuits. Figure 286 shows the potential-switch circuit for a drum-type elevator, and in addition to the other devices it has a slack-cable switch, which will be opened should the car or counterweights land on the bottom of the hatchway and the cables become slack.

On a traction-type machine the cables cannot become slack, so the slack-cable switch is replaced by a switch under the car, which

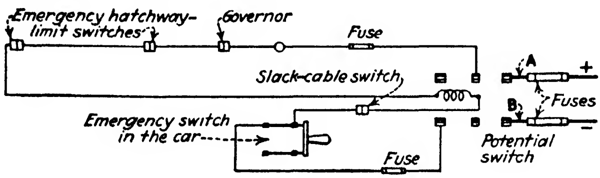


Fig. 286.

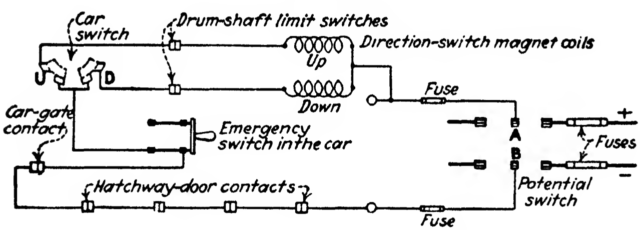


Fig. 287.

Figs. 286 and 287.—Potential- and direction-switch coil circuits on a drum-type elevator controller.

is opened should the governor set the safeties on the car. In Fig. 288 the hatchway-limit switches are shown double-pole as in Fig. 291, while in Fig. 286 these switches are single-pole as in Fig. 292. These switches are mounted at the top and bottom of the hatchway and are opened by a cam on the car striking roller *R*.

On some drum-type installations both hatchway-limit switches in the potential-switch circuit are mounted at the bottom of the hatchway, so that one will be opened by the car and the other by the counterweights. The latter occurs if the car goes too far above the top landing. As has been previously discussed, if any of the devices in the potential-switch coil circuit are not making

proper contact, it will cause the potential switch not to hold closed. In all cases of trouble caused by the elevator's failing to start, the first thing to make sure is that the power circuit is complete up to the potential switch.

Testing the Power Circuit.—Too much emphasis cannot be laid on being sure that the power circuit is alive and complete to

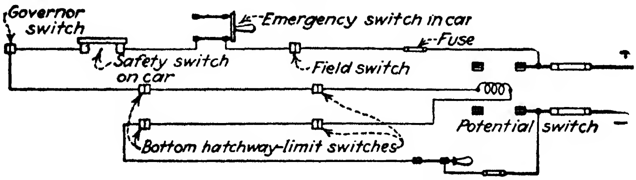


Fig. 288.

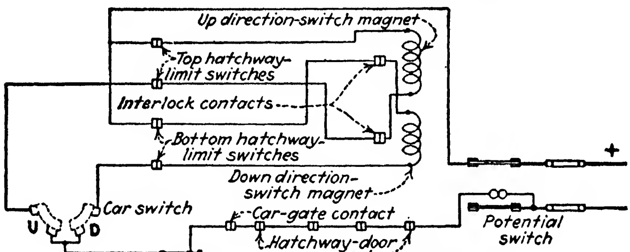


Fig. 289.

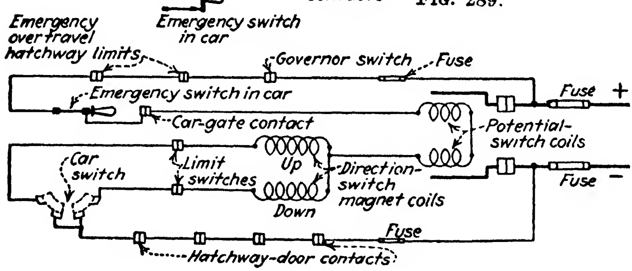


Fig. 290.

Figs. 288 to 290.—Potential- and direction-switch coil circuits on a traction-type elevator controller.

the controller, and the only sure test is that made with a lamp or voltmeter connected across the line. On a three-wire 110- and 220-volt circuit with grounded neutral, tests for power on the 220-volt circuit are sometimes made with a 110-volt lamp, connected one side to ground. That is, one side of the lamp is grounded and the other lead is connected first to one side of the circuit and then to the other. If a light is obtained on both tests, it is assumed that the power circuit is all right.

Experience has shown that such a test cannot always be relied upon. In one case in mind the line and potential switch for the elevator were mounted on a panel separate from the controller. This panel was mounted on the wall, which made it impossible to see the wiring. One day the potential switch on the elevator would not stay closed. A test was made of the power lines with a 110-volt lamp, one side of which was connected to ground. Since a light was obtained on all four terminals of the fuses, it was assumed that the trouble was in the potential-switch coil circuit. This was tested through with the lamp and found to be complete, but when the potential switch was closed, the coil would not hold it closed.

Considerable search was made for the trouble when an attempt was made to start the elevator while holding the potential switch closed by hand. This revealed that the motor would not start and that the trouble was somewhere else than in the potential switch. The baffling part of the difficulty was that according to all tests made with the lamp to ground, the circuits were complete.

The mystery was solved by connecting the lamp across the load ends of the fuses. It was then found that the circuit was dead, although it tested all right to ground. Taking out the fuses and testing them showed one to be blown, and when replaced with a good one, elevator service was restored. The reason why both ends of the fuses tested alive to ground was accounted for by finding that a pump motor switch, on the same panel with the elevator switch, was connected between the elevator circuit fuses and the potential switch, as at *A* and *B*, Fig. 286.

The float switch controlling the pump motor was closed and completed the circuit from the motor end of the good fuse around to the motor end of the fuse that was blown. Although both fuses on the load ends tested O.K. to ground, they were both the same polarity. This incident indicates that it is possible to have a circuit to show alive when tested to ground even when one of the fuses is open, therefore such tests are not to be relied upon, especially if the fault is causing unusual difficulties.

Testing the Direction-switch Control Circuits.—After it has been ascertained that conditions in the power circuit are correct for operating the elevator, as indicated by the potential switch remaining closed and the motor failing to start when the control switch in the car is put in the on position, then attention should be given to the direction-switch circuits. There are two condi-

tions that will generally be met with in a full-magnetic type controller, that is, a controller operated by a car switch. One, when the car switch is placed in the on position, the direction switch on the controller closes, and two, when the direction switch fails to close.

From either one of these conditions a fair idea may be formed as to where the trouble may be. If the direction switch responds to the control switch in the car, it is known that this circuit is not only alive but is in operating condition. Since the direction

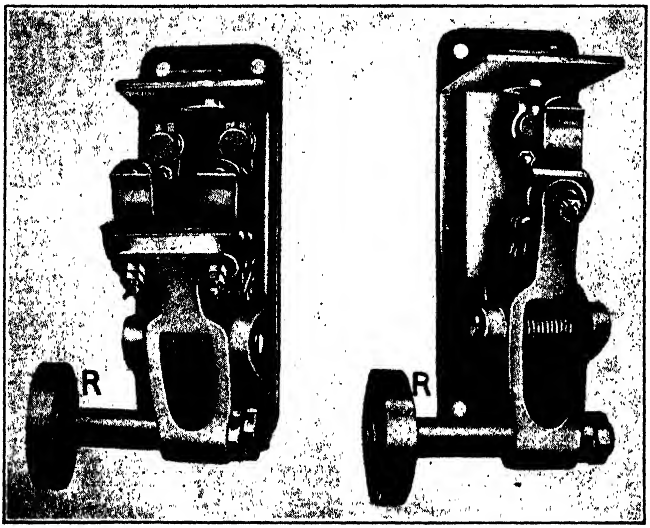


Fig. 291. Fig. 292.

Figs. 291 and 292.—Double-pole and single-pole hatchway-limit switches.

switch closes and the motor does not start, it would indicate that the trouble is in the motor circuit itself. If the motor will not start with either one of the direction switches closed, it is a pretty sure indication that the trouble is not in the direction switches, but in other parts of the motor circuit. It is possible that the circuit could be open in one switch, but the motor circuit in both switches being open at the same time seldom occurs, therefore if the motor fails to start with either reverse switch closed, the possibilities of the trouble being in these switches is remote.

Having eliminated the direction switches as being the source of trouble, the most likely places are in the motor or in the starting resistance. The starting resistance may be tested by connecting

a lamp in series with the armature and closing all the accelerating switches; this will cut all the resistance out of circuit, and if the trouble is in this part of the circuit the lamp will light. These tests were described more fully on page 390.

If the direction switches fail to close, it is an indication that their coil circuits are not complete. Figure 287 shows the direction-switch circuits for a drum-type machine. Starting at A on the potential switch, the circuit is through a fuse on the control board, then through either the up- or down-motion direction-switch magnet coil, depending on the position of the car switch. From the direction-switch magnet coils the circuit continues through the drum-shaft limit switches, the car switch, one side of the emergency switch in the car, car-gate contact and the hatchway-door contacts to the negative side of the line.

Any of these devices not making contact will prevent the direction switches from closing. It is possible that one switch will close and the other will not, at other locations than the terminal landings. For example, if the circuit on the down-direction switch coil is interrupted between the coil and the car switch, this switch will not close when the car switch is in the down position, but this would not interfere with the circuit of the up-direction switch coil. On the other hand, if the open is between the car switch and the – side of the line, it will interrupt the circuit of both direction-switch coils and neither will respond to the car switch. These two conditions give an idea whether the trouble is in the individual coil circuit or in that part of the circuit that is common to both coils.

If neither one of the direction switches will respond to the car switch, a test can be made to determine if the trouble is in the direction-switch coil circuit or in the power circuit, by closing one of the direction switches by hand. With the power circuit complete the motor should start when the direction switch is closed by hand, or at least an arc should be obtained at the contacts when the switch is allowed to open. The absence of these indications would show that power was not getting to the controller.

When closing either of the direction switches by hand, care must be exercised to be sure that it is safe to move the car and also not to run the car by the terminal landings, since, unless the equipment is protected with emergency limits and a potential switch, there is danger of pulling the car or counterweights on a drum-type machine, into the overhead work with disastrous results.

On some types of controllers an operating switch is provided on the control board for operating the car from this point. Such an arrangement is shown in Fig. 293. When the single-pole knife switch *S* is the up position, as shown in the figure, the car can be operated from the car switch only. Throwing switch *S* to the down position allows operating the car from the control switch *C*. This switch is generally connected in the circuit so as to cut out all safety switches in the circuit with the exception of the ter-

Fig. 293.—Gurney single-speed full-magnet direct-current elevator control panel.

minal floor limits, and can operate the car on the first speed only. If the car will operate from the control-board switch and will not from the car switch, it shows that the trouble is in the part of the circuit not included in the circuit of the former. This information would assist in narrowing down the number of places to look for the trouble.

Assume a case where there is no operating switch on the control board and the motor will start when the direction switches are closed by hand, but neither of these switches will respond to

the car switch. One of the first things to do is to examine all the contacts in the car-switch circuit. These will vary with the type of installation and the locality. In Figs. 287, 289 and 290 gate and door contacts are shown. On many installations these are not used, but when they are, they should be one of the first sources of the trouble looked into. On cars provided with an emergency switch for short-circuiting the door contacts, the test for the trouble in these contacts can be made by closing this switch. If the car can be operated with the door contacts out of circuit and not when they are in, some of these contacts are out of order.

Unless the car switch is given careful attention, the contacts may become worn or out of adjustment and fail to complete the circuit. If the trouble cannot be found in any of the limit and safety switches, attention should be given to the wiring. If there is a fuse in this circuit, it should be one of the first things tested. Owing to the bending of the traveling cable, which makes the connections between the hatchway wall and the car, it is always a potential source of trouble. When the trouble is in the traveling cable, it is likely to disappear temporarily if the car is moved by closing the direction switches on the control board by hand. Where trouble of this kind is being experienced, the traveling cable should be renewed, as locating the open-circuit in this cable and repairing it, generally gives only temporary relief, as previously explained.

Direction switches are generally equipped with an interlock so that one switch must be open before the other can close. Where this interlock is electrical, it consists of contacts on the switches through which the coil circuits are made. The contact for the down-direction switch coil is closed when the up switch is open and vice versa. These contacts are indicated on Fig. 289. On such switches unless the interlock contact on one switch completes the circuit, the other switch cannot be closed from the car switch. A mechanical type of interlock is shown at *L*, Fig. 294, and consists of a bar fulcrumed in the center so that when one switch closes, it holds the other open.

On some types of controllers it is possible for the direction switch to get out of adjustment so that the magnet coils cannot close them. Direction switches of this type are shown in Fig. 294, and the adjustment is by a screw at *B*. The closer the armature *A* is brought to the magnet core the greater the pull

that will be developed for closing the switch. On this controller there are two coils on each direction switch. There are also two potential switches D and D'. As shown in Fig. 290, all four coils are in series. On this controller the potential switches open and close with the direction switches, and anything preventing one

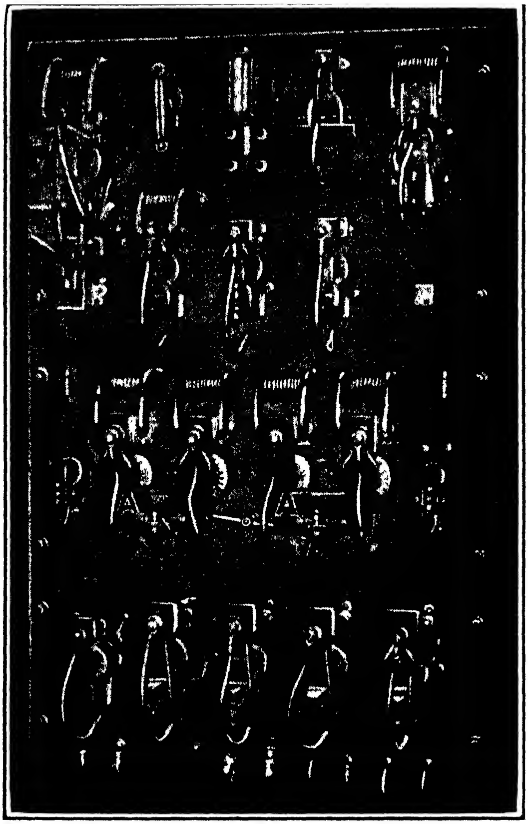


FIG. 294.—Payne three-speed direct-current control panel.

from closing will prevent the other, with the exception of a short-circuit in one of the coils. For example, a short-circuit of coil D would prevent this switch from closing, but the other potential switch and one of the direction switches will close, depending on the position of the car switch.

On some types of controllers, using horizontal solenoids for closing the reversing switches, the movable core has been known

to wear into the brass sleeve of the coil to such an extent as to prevent the switch from closing properly. On such switches dirt is liable to gum up the core and sleeve and prevent the switch from returning to the off position to close the interlock contacts, thus causing unsatisfactory operation of the elevator. In other cases the contactors are made sluggish in their operation by the lack of lubrication on the bearings that support the contactor

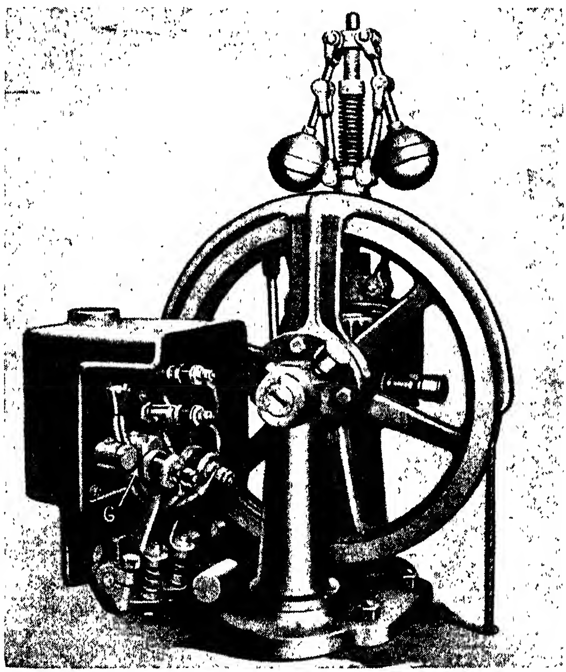


FIG. 295.—Governor with safety switches.

arm, such as those shown at *A*, Fig. 293. A little lubrication on the bearing during the regular inspections will insure satisfactory operation of the contactors. Grounds in the wiring or short-circuits in the direction-switch coils will cause the fuses to open in these circuits and prevent operation of the switches.

The direction-switch coil circuits that have been discussed are essentially the same on all types of elevators, although there may be considerable difference in the safety devices included in these circuits. On a drum-type machine the terminal limits will be

on the end of the drum shaft, as at A in Fig. 282, whereas on a traction-type machine, Fig. 272, these switches may be mounted in the hatchway, near the terminal landings and opened by a cam on the car. Another arrangement of the limit switch on a traction machine is to mount the switches on top of the car, in which case they are opened by a cam in the hatchway.

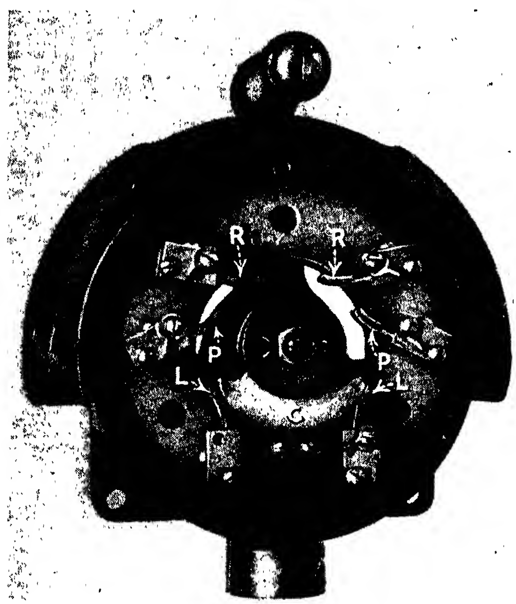


Fig. 296.—Two-speed car switch.

In some installations one or more switches are on the governor, such as shown at G, Fig. 295; in other cases such switches may be omitted.

Direct-current elevator controllers are designed for a wide variety of speeds. For the slow-speed machines only one speed is used, in which case there would not in general be over four contacts on the car switch such as L and P, Fig. 296. On a two-speed controller there are six contacts, as in Fig. 296, the two top contactors giving the second speed. For high-speed machines as many as six different speeds may be obtained, in which case the car switch may have as many as 14 contacts. However, in any case the first two contacts to make, in either direction, when the

car switch is moved to the on position, is the direction-switch circuit.

On machines that operate at more than one speed the cause of the machine's failing to come up to full speed after starting will depend upon the type and make of controller, and a careful study of high-speed elevator control circuits is to be recommended. However, if the various contactors on the controller and the car switch and limit switches are kept in good condition, about 90 per cent of the cause of trouble will be eliminated.

CHAPTER XXI

LOCATING FAULTS IN ALTERNATING-CURRENT MOTORS AND CONTROLLERS

Types of Alternating-current Motors.—Faults in alternating-current motors used in elevator service will be the same as when these motors are used for other applications, except as the motor's operation may be affected by the conditions of the elevator machinery and the controller. With direct-current, shunt-type or compound-type motors are used for elevator service. In alternating-current elevator practice a wider diversity of

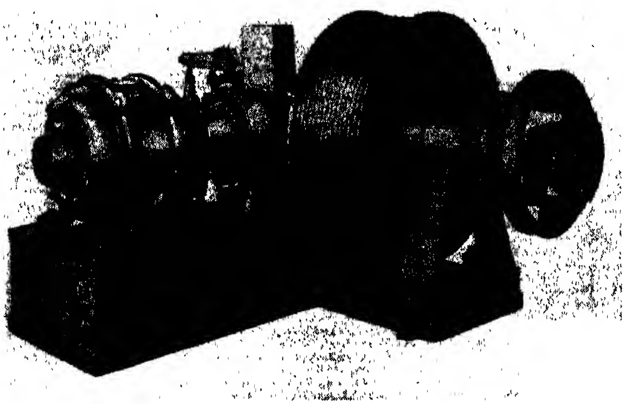


FIG. 297.—Drum-type machine driven by single-speed squirrel-cage motor.

motors is used and this somewhat complicates the problem of locating troubles when they do occur. Although single-phase type motors have been used to drive elevator machines, these have been exceptions to general practice, therefore only the polyphase types will be considered.

On alternating-current circuits polyphase motors of both the squirrel-cage type, Fig. 297, and the wound-rotor type, Fig. 298, will be found in elevator service. For slow-speed machines up to about 200 ft. per minute the simple squirrel-cage or wound-rotor type motors are used. For medium-speed drum type or

geared-traction machines, Figs. 299 to 301, multi-speed motors are used. These motors may have two windings in the same slots, each winding grouped for a different number of poles; for example, 8 and 4 poles or 12 and 4 poles, giving a speed ratio of 2 to 1 or 3 to 1 as the case may be. In some cases, only one winding is used, and this is regrouped for two different numbers of poles by the control equipment.

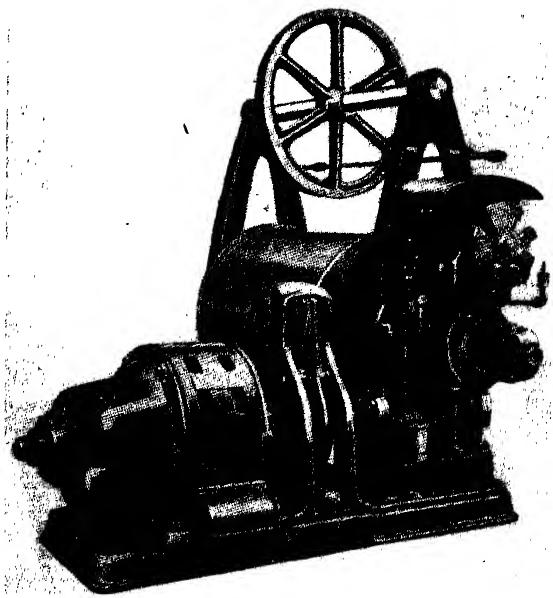


FIG. 298.—Drum-type machine driven by wound-rotor motor.

It is also the practice to use two different motors. The stators of the two motors may be mounted in the same frame and the rotors keyed to the same shaft so that the two motors form a single unit, Fig. 301. Control equipment is provided to cut into service first the slow-speed motor and after acceleration on this motor has been accomplished, the high-speed winding is switched into service and the slow-speed winding disconnected.

Where a two-speed wound-rotor motor is used, the rotors must have two windings grouped for the same number of poles as in the stator and these windings handled in the same way as the stator windings. On account of being unable to obtain proper

speed control and the difficulties of designing and building very slow-speed alternating-current motors, direct-traction alternating-current elevator equipments are not used. Where it is desirable to go to high-speed elevators above 400 ft. per min. and only alternating current is available, direct-current equipment is generally installed and the alternating current is converted into direct current for the power supply.

Classification of Faults.—All the different types of alternating-current motors used for elevator service, referred to in the foregoing, affect the condition under which trouble may be experienced with these motors. Although the conditions under which

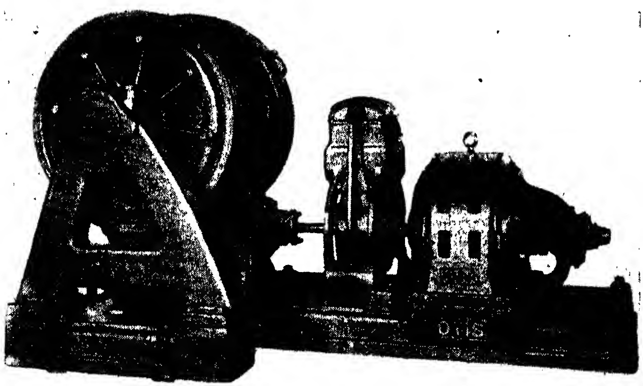


FIG. 299.—Geared-traction machine driven by wound-rotor motor.

the trouble may occur may vary somewhat with the different types of motors, practically the same difficulties may develop in all types. These troubles may be divided into: Noisy operation; motor fails to start; torque too low; speed too low; speed too high; heating; sparking at the brushes on the slip rings, where the motor is of the wound-rotor type; and reverse rotation.

With alternating current, the quality of the power supply is affected not only by the voltage, but also by the frequency of the system. The torque of an alternating-current motor varies as the square of the voltage, therefore a comparatively small variation in voltage may materially affect the torque of the motor. For example, if the voltage is reduced 10 per cent on a motor, the torque it will develop will be only 81 per cent of that at normal voltage. It is quite readily seen that if the voltage is materially

reduced, there is a liability of the motor's not being able to start its full load, or if it does start the load, acceleration will be slow. Where the elevator is making floor-to-floor stops, the greater part of the time is required to accelerate, therefore anything that lengthens the acceleration period will slow up the service.

Overvoltage on an alternating-current elevator motor may also have undesirable effects. A 10 per cent increase in voltage above normal will cause the motor to develop a torque 121 per cent of normal, which may increase the rate of acceleration of the elevator to a point where it will be unpleasant for the passengers

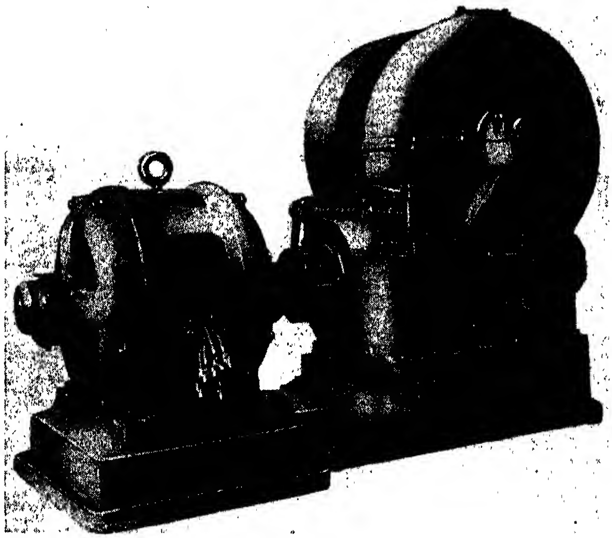


FIG. 300.—Geared-traction machine driven by two-speed squirrel-cage motor.

in the car. It may also cause excessive noise in both the motor and controller. High voltage increases the current through the magnet coils and increases the pull on the contactors, which may cause them to slam unduly, resulting in increase in maintenance.

Checking Power-circuit Voltage.—When checking voltage on an elevator, it is not sufficient to take this reading at any particular load or time. What should be obtained, is a record for a period of a day or a week on a recording voltmeter. It is better still, if one of these meters can be connected to each phase for the test period. It is quite as important that the voltage be balanced

on all phases as it is that it be correct on any particular phase. Where power is supplied over long transmission lines, unless automatic regulation is provided there may be wide variation in the voltage over the 24 hours of the day. In the daytime, when the load is heavy on the system, the voltage may be low and at night or during other light-load periods the voltage may be high. A variation in the voltage, applied to an alternating-current motor,

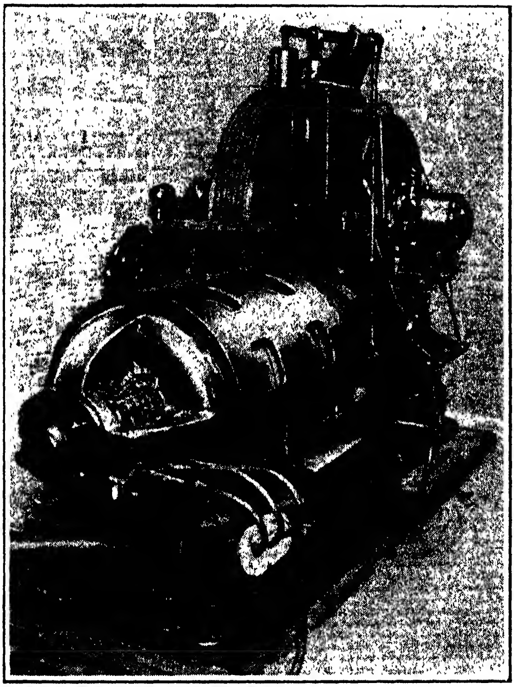


FIG. 301.—Geared-traction elevator machine driven by double motor having a 1 to 3 speed range.

from 10 per cent above normal to 10 per cent below normal, will cause the torque to be 50 per cent higher at the high voltage than at the low voltage; that is, 121 per cent torque is 50 per cent greater than 81 per cent.

With this wide variation in torque it may be impossible to adjust the control equipment to give satisfactory operation at all periods of the day. Adjustments that would give smooth acceleration at the low voltage may cause the motor to start with a jerk at the high voltage. On the other hand, adjusting the con-

trol for satisfactory operation at the high voltage may result in slow acceleration at low voltage, or the motor may actually stall.

Effects of Frequency Variations.—If trouble is being experienced with the torque and speed of an alternating-current motor, the frequency of the power system should also be checked. The speed of the motor varies directly as the frequency. A 5 per cent increase in frequency will cause a 5 per cent increase in speed, and likewise a 5 per cent decrease in frequency will cause a 5 per cent decrease in speed.

A variation between 57 and 63 cycles on a 60-cycle system will cause a variation of about 10 per cent in speed of the motors on the system. An increase in frequency will tend to decrease the torque of the motor where a decrease will tend to increase the torque.

A change in frequency also affects the magnets on the controller. An increase in frequency will decrease the current through the coils and vice versa for a decrease in frequency. With a decrease in frequency the increase in current in the magnet coils may cause excessive heating. From the foregoing it is evident that close voltage and frequency regulation are desirable for alternating-current elevator motors and controllers.

Noisy Operation.—Noisy operation of alternating-current motors is more prevalent than with direct-current motors. As an alternating-current type, anything that might occur in the former to cause unusual noise may be doubly objectionable. In any motor the rotating member out of balance will cause vibration and noise in operation. With an alternating-current motor, in addition to mechanical vibration there is also magnetic vibration to contend with, and the latter is more likely to cause trouble than that occurring from mechanical causes. Mechanical vibration, when once eliminated, is not likely to occur again, but magnetic vibration may be produced from a number of causes that can develop in the normal operation of the machine.

Before attempting to diagnose a case of noisy operation, it is well to determine if the cause is mechanical or magnetic. This may be done by disconnecting the motor from its load and then connecting it to the line. After it comes up to speed and is operating unusually noisy, if the switch is opened and the motor continues to vibrate, it will be known that mechanical causes are producing the noise. On the other hand, if when the switch is opened the noise immediately disappears, it will be known that

the presence of current in the windings is the cause of the trouble.

Worn bearings or the rotor loose on the shaft may cause noisy operation of the motor. If the bearings become worn so as to allow the rotor to get too close to the stator core, the motor may fail to start and develop a very heavy vibration. If the motor is allowed to remain connected to the line under this condition, the vibration will be likely to injure the windings, either owing to excessive heating or vibration or both. With a squirrel-cage rotor, loose connections between some of the bars and end rings will cause unequal distribution of the current in the rotor and are likely to produce noisy operation. Vibration from this cause generally disappears when the motor comes up to speed. With a wound-rotor motor that had a number of grounds in the rotor winding, noisy operation developed.

Other causes of noisy operation are: Voltage too high; voltage unbalanced; open-circuits in part of the stator windings; short circuits in part of stator windings, which will generally be accompanied by excessive heating; and single-phase operation. The last is generally due to causes outside the motor, such as an open phase in the external wiring.

Failure of the Motor to Start.—A polyphase motor cannot start single-phase, but will run single-phase if once brought up to speed and not too heavily loaded. Where a motor is started from reduced-voltage taps on an auto-transformer and thrown to full voltage after coming up to speed, it is possible to have an open-circuit in one phase of the full-voltage wiring and have the connections complete on reduced voltage. Under these conditions the motor would start polyphase and would operate single-phase during the running period. This, however, will generally be accompanied by excessive heating of the winding, noisy operation, reduced speed, and if the motor is heavily loaded it may stop after being thrown onto full voltage, in which case the fuses or circuit breaker will generally open.

Failure of an alternating-current motor to start when the load is free to move, may be caused by interruption of the power supply due to opening of the protective devices or otherwise, or to an opening in one phase of the wiring. If the power supply is completely cut off from the motor, when the starting switch is closed there will be no humming noise emitted by the motor. If only one phase is open, the motor will not start but will develop a loud roaring noise. Worn bearings that will allow the rotor to come

in contact with the stator will cause the motor not to start; this fault will be accompanied by a loud roaring noise when power is applied to the stator. In this case, sometimes the motor may start while at other times it may not.

If a wound-rotor motor is connected to the line with the rotor resistance cut out, the motor is very likely not to start and will take a current from the line that will open the protective device. Opens in the resistance of wound-rotor motors will cause it to fail to start, but this condition will be accompanied by a loud roaring noise. A similar condition would exist with a squirrel-cage type motor in case a number of the bars are broken from the end rings. Grounds in the stator windings or short-circuits between phases may cause failure to start, although the conditions will generally cause the protective device to open.

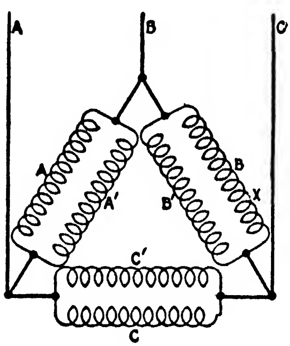


Fig. 302.—Diagram of two-parallel delta-connected winding.

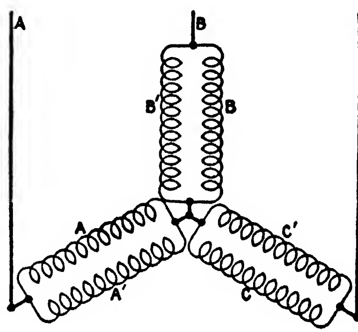


Fig. 303.—Diagram of two-parallel star-connected winding.

Low Torque.—Low torque may be due to low voltage, poor connection between the bars and end rings of squirrel-cage motors, open circuits, short circuits and grounds in the rotor winding of wound-rotor motors. Open-circuits, short-circuits, or grounds in the stator windings may cause low torque in addition to the other effects already referred to. If one phase is completely open, then the motor will not start. Many motors are wound with multiple circuit windings. For example, each phase has two windings in parallel, as in Figs. 302 and 303. If one of the windings were open at X, Fig. 302, there would be two groups of windings in parallel between leads A and B, also between leads A and C, but only one winding between leads B and C. Such a condition in the windings would reduce the torque and cause the

motor to take an unbalanced current from the line. Ammeters connected in the circuit would show the current unbalanced, but this should not be taken as an indication of a fault in the windings, since unbalanced line voltage would have a similar effect. If the motor is started cold and allowed to run for a short time, the phase with only one winding in circuit will heat more than the others. However, after it has been decided that the cause of the trouble is not external, the surest test is to break the windings into their parallel groups and test through them with a lamp.

Testing for Faults in Motor Windings.—If low-voltage direct-current is available, the windings may be excited from this source and readings taken on the coil terminals with a millivoltmeter. If a section of winding is open-circuited, no reading will be obtained on the coils until the open is bridged by the meter, when a heavy deflection of the needle will occur. In making this test care should be exercised to take readings on coils only and not between phases, or misleading results may be obtained.

Another thing, with a delta-connected winding, the whole winding will be excited by connecting any two leads to the power source, where with a star-connected winding, Fig. 303, only two phases will be excited. In the delta-connection one phase will carry about double the current that the other two will, consequently the readings obtained on all three windings will not be equal. The winding carrying the larger current will give the greatest deflection on the millivoltmeter. To connect the voltmeter to the coil terminals, sharp steel points can be used as test lead terminals to pierce the insulation and make contact with the coils without removing the insulation.

Causes of Low Speed.—Low speed may be due to low frequency, low voltage, rotor rubbing on the stator, poor connections or open-circuits in the rotor windings, open-circuits or short-circuits in the stator windings; the latter will generally be accompanied by excessive heating of the windings.

Heating of the windings may also be caused by high voltage, open-circuit in part of one phase, as previously explained, and the rotor rubbing on the stator. In elevator service overloads will rarely be the cause of heating.

Sparking at the Slip Rings.—Sparking at the slip rings of a wound-rotor motor is generally due to flat spots on the rings. These flat spots may be due to hard and soft spots in cast-iron rings or spongy spots in bronze rings; vibration that causes the

brushes to break contact with the ring; brushes making poor contact or sticking in the holders; chattering of the brushes; and distortion of the rings at operating temperatures. However, in elevator service sparking at the slip rings of the motor is not generally a very serious trouble.

With alternating-current motors, if a phase is reversed accidentally on the power system, it will cause the motor to be reversed. This is a very dangerous condition and should be protected against with reverse-phase relays. Such relays will generally also protect against single-phase operation and should be installed on every polyphase alternating current motor used on elevator service. Reversal of phases on alternating-current power systems has been the cause of wrecking elevator machinery.

Applying Alternating-current to Elevators.—There are two methods of applying alternating current to elevator service: (1) convert it into direct current and use direct-current elevator equipment, and (2) apply it direct by the use of suitable alternating-current motors and control equipment. The former is usually done only for high-speed elevators, and in such cases the troubles that may develop in the elevator equipment are the same as those for any direct-current equipment. The development of satisfactory magnetic contactors and a brake magnet for alternating-current motor control has offered many difficult problems. To get away from these difficulties alternating-current motors have been applied to elevator service with direct-current control equipment, the current for operating the controller being supplied by a small motor-generator set driven from the alternating-current power supply. In such installations the controller troubles will be practically the same as with direct-current equipment, but the motor troubles will be those of the particular type of alternating-current machine used, as will be subsequently discussed.

Slow-speed Elevator Service.—In slow-speed alternating-current elevator service the motor may be connected directly across the line. This allows the use of the simplest kind of control equipment. In some of the earlier types of elevator equipment the controller was only a knife-type reversing switch mounted directly on the shipper wheel. This switch was closed to one position or the other according to the movement of the control equipment by the operator in the car. Figures 304 and 305 show elementary diagrams of the motor circuits for such a control

equipment for a three-phase squirrel-cage motor. The arrow heads indicate the instantaneous direction of the current, and it will be seen that the direction of the current in the motor windings B and C is reversed in Fig. 305 from that in Fig. 304. Such equipment is simple but, as some of the earlier types were designed, was a source of considerable trouble, due to burned and loose contacts, particularly if the elevator service was heavy.

Such control equipment gives the motor and elevator machinery practically no protection other than overload, and this only

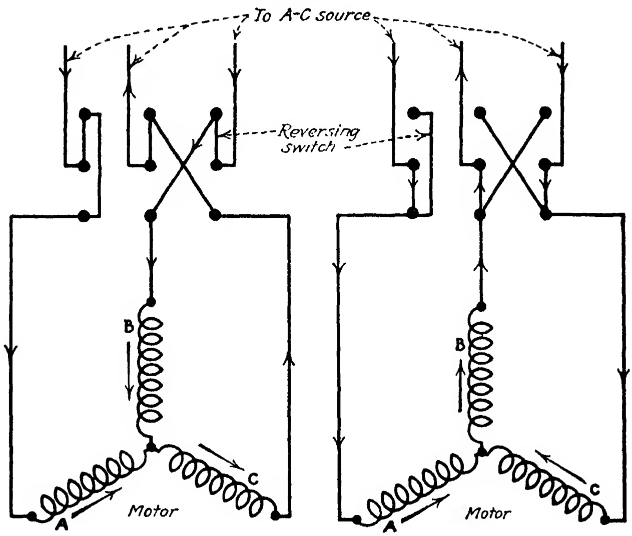


Fig. 304. Fig. 305.

Figs. 304 and 305.—Diagrams of connections of a three-phase motor to a reversing switch.

if the motor happens to be properly fused. The latter was rarely the case with the old-type squirrel-cage motors, since the starting current was so high. When the fuses were made large enough to take care of the starting current, they were too large to give proper protection to the motor during normal operation.

Open Phase and Reverse Phase.—If one phase is open on a two- or three-phase motor, the motor cannot start. If the machine is connected to the line and left with one phase open, the heavy current flowing in the other part of the winding will overheat and destroy the motor's insulation. Motor windings have been burned out due to one phase opening, by a blown fuse

or otherwise, and the operator pulling the control equipment to the on position and leaving it there, after it was found that the elevator would not start.

A direct-current motor cannot be reversed by interchanging the line wires, but if the wires of any one phase are interchanged on a line supplying polyphase alternating-current motors, it will cause a reversal of the motors' direction of rotation. There are a number of cases on record where elevator motors have been reversed in this way and some of them with disastrous results to

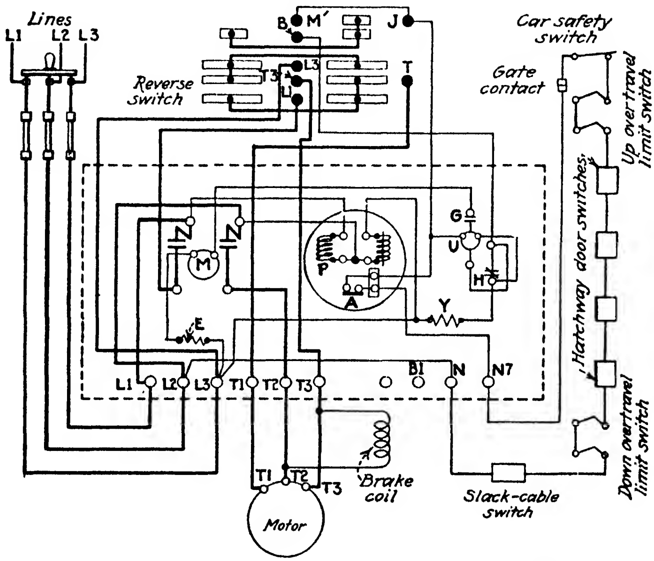


FIG. 306.—Wiring diagram of controller, Fig. 307, for use with hand-rope controlled elevator.

the elevator equipment. Therefore an elevator alternating-current motor, in addition to being protected against overload, should also be provided with open-phase and reverse-phase protection. The diagram, Fig. 306, shows the wiring for such a controller, as built by the Cutler-Hammer Manufacturing Co., for use on an elevator controlled by a hand rope in the car. The control for a traction machine would be the same except that the slack-cable switch would be left out.

The complete control equipment corresponding to the diagram, Fig. 306, is shown in Fig. 307. Reversing of the motor is done by a cylindrical-type switch, Fig. 308, and shown at *R*, in Fig.

307. The phase-failure and reverse-phase relay is shown at P, an undervoltage relay at U and a magnetic line contactor at M. These parts are indicated on the diagram. In this diagram the car safety switch, overtravel limit switches, hatchway-door switches, gate-contact and slack-cable switches are common to both direct-current and alternating-current controllers.

Tracing out the circuit for the line contactor M, it is found to go from line terminal L_2 through all the protective devices con-

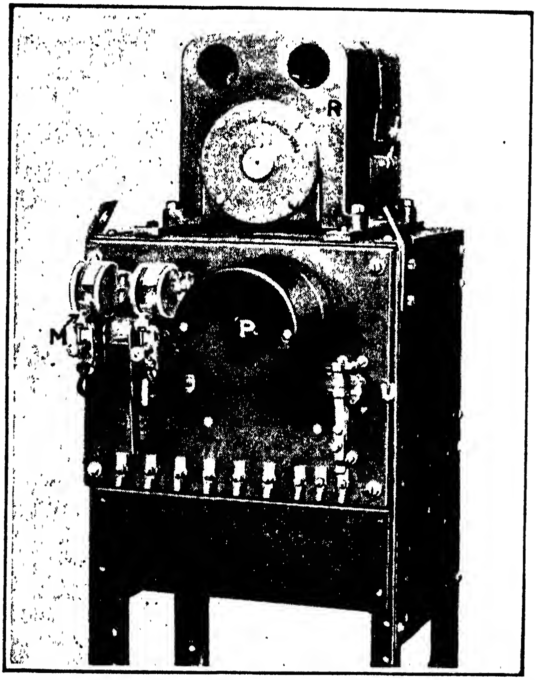


FIG. 307.—Semi-magnetic type alternating-current controller.

nected between N and N_7, then through contact A on the reverse-phase relay P, through the coil on the undervoltage relay U and to line terminal L_3, if the reverse switch is in the off position. The energizing of this circuit holds the undervoltage contactor closed as long as the circuit remains energized and completes the circuit for the line contactor coil M. This circuit is from L_2 through all the protective devices included in the undervoltage relay-coil circuit and to M' on the reverse switch. When the reverse switch is closed to either position, the circuit is completed from M' to

B through contact *G* on the undervoltage relay *U* and coil *M* to L_3, thus energizing this coil and causing it to close its contacts, and completing the circuit for the motor. The motor contacts on the reverse switch are so arranged that they close before switch *M* and open after switch *M*, so that all the making and breaking of the main circuit is done on this switch, which is designed for this class of service. Since there is no current broken on the reversing-switch contacts, these contacts will cause little trouble if properly adjusted and the cylindrical surface lubricated with a little clean vaseline.

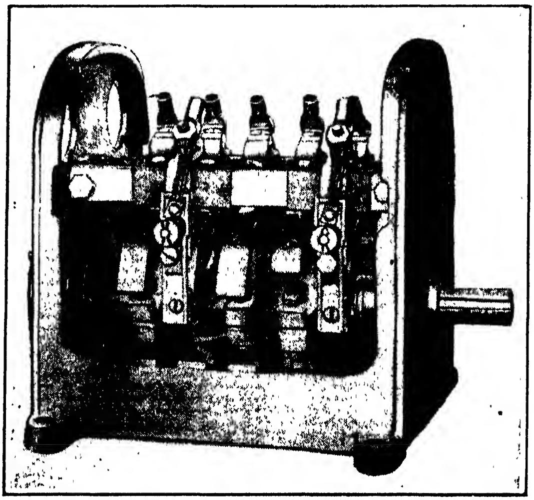


FIG. 308.—Cylindrical-type reversing switch.

Undervoltage Protection.—The undervoltage relay is to prevent the car starting unexpectedly after a voltage failure, if the control happens to be left in the run position. On a full magnet-type control the car switch is made self-centering so that it cannot be left in the on position, but the hand-rope control will remain in almost any position in which it may be placed. The undervoltage release also prevents the car from starting should the operator be holding the controller in the on position and someone close the landing doors or car gate, if door and gate switches are used, without first moving the controller to the off position. If contacts *M'B* are closed on the reverse switch, as they are with the switch in either full-on position, a circuit is

provided from contact A on the reverse-phase relay P through $M'B$ on the reverse switch, to H on the undervoltage relay, through resistance Y to L_3. This shunts out the coil on the undervoltage relay U and it cannot close its contact. When the reverse switch is in the neutral position, contacts $M'B$ are open and the coil of the undervoltage relay U is in circuit, as previously explained. Closing of the undervoltage relay opens contacts H and prevents the relay's coil being short-circuited when the reverse switch closes, but this does not interfere with the circuit for coil M, which has been previously described.

If any of the safety devices in the undervoltage relay's circuit are open or making poor contact, the relay cannot close and the control will be inoperative. A check can be made to determine if the trouble is in the safety devices or in the controller, by temporarily connecting N and N_7 terminals together. If the trouble is in the car or hatchway safeties, the undervoltage release should close. In making this test care must be exercised since, with terminals N and N_7 short-circuited, no protection is provided against the car or counterweights being pulled into the overhead work. Therefore the car should not in any case be started with the N and N_7 terminals short-circuited.

If it is found that the undervoltage relay will close with the car and hatchway safety devices cut out of circuit, it is known that the trouble is somewhere in this part of the circuit. On the other hand, if the undervoltage relay does not close, it will be known that the trouble is somewhere at the controller. One of the first things to test is the fuses and make sure that power is getting to the controller. When this has been made sure of, then the reverse-phase relay should be examined to see if its contacts are closed. If it is in normal position, the circuit through its contacts can be checked by disconnecting the leads from contacts, A, at N_7 and at relay U, and testing through with a test lamp. If contacts A are causing the trouble, the elevator may be operated temporarily by disconnecting the leads from contact A and connecting them together. When this is done, care should be taken, when first starting the car, to make sure that it runs in the direction corresponding to the position of the controller.

In case of a reversed phase, the fault can be corrected by crossing the wires of any one phase at the line switch. However, this should not be done until it is ascertained how the phase was reversed on the line and what is going to be done to correct the

trouble. If the trouble was corrected at the motor's switch and the elevator put into service, then afterward to make conditions normal on the line a phase is reversed, the elevator will again be operating in the wrong direction on the controller. To avoid such an occurrence it should be definitely determined what is going to be done on the line.

Where trouble is being experienced with improper operation of the reverse-phase relay, the manufacturer's instructions should be consulted carefully. In case it is a type with a mercury switch and this switch fails, it will probably be best to send the relay back to the factory to have a new one installed. The adjustment of this switch is a sensitive operation and should not be attempted by anyone except a competent worker.

After the undervoltage relay closes, if the line contactor *M* will not close, two sources where the trouble may be are the contact on the undervoltage relay and contacts *M'B* on the reverse switch. A resistance in series with a coil is always a potential source of an open-circuit. In Fig. 306, *Y* is in series with the undervoltage relay coil *U* and resistance *E* is in series with coil *M*. In case of these contactors being inoperative, the resistances corresponding to the contactor in trouble should be tested through with a lamp. In many cases resistance coils are of comparatively high resistance. If tested through with a lamp, the latter may not glow if of the carbon type, so that care must be exercised in making such tests, if wrong conclusions are to be avoided.

Faults in Contactor Magnets.—Alternating-current magnets require careful adjustment if they are to operate quietly. They are usually designed with a closed magnetic circuit, as in Fig. 309. The coil *C* is mounted on a laminated iron loop, and a laminated armature *A* seats on the two pole faces *L* and *L* when the contactor closes. The pole faces and armature are ground to a good fit. Any dust, lint or oil collecting on these surfaces to prevent the armature from properly seating may cause the contactor to be noisy. In the pole face of these contactors there is a copper loop, known as a shading coil. If this loop becomes broken, it will also cause noisy operation. On some controls, rotating types of magnets are used. These operate similar to small polyphase motors, and are sometimes called non-sealing magnets.

Current taken by a coil on an alternating-current circuit is limited by the ohmic resistance of the coil's circuit and by the counter-electromotive induced in the coil, just as in the primary

winding of a transformer. When the coil circuit, Fig. 309, is first closed, the contactor is open; consequently there is a long air gap in the magnetic circuit. This long air gap does two things: it greatly reduces the number of magnetic lines set up in the core per ampere in the coil, and reduces the counter-electromotive force in the coil so that the current flowing will be considerably larger than when the magnetic circuit is complete iron, as when the contactor is closed. On this account if the current is left on a contactor coil, when the contactor does not close it is likely to burn out in a short time. If trouble is being experienced with a contactor coil burning out, the possibility of the contactor not closing should be looked into carefully. On direct current, a coil might have a small part of its winding short-circuited without causing serious trouble. On alternating current the short-circuited section of a coil becomes a short-circuited secondary of a transformer and might prevent the coil from closing the contactor, or if the contactor did close, the current flowing would be sufficient to cause the coil to burn out in a short time.

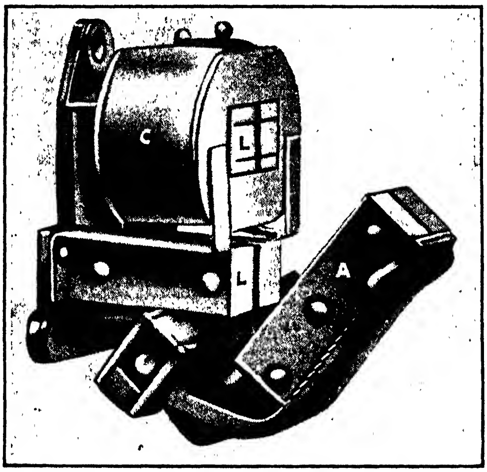


Fig. 309.—Alternating-current contactor magnet.

Speed Too High.—It is quite general practice, where single-speed high-resistance squirrel-cage induction motors are used on slow-speed elevators, to start the motor with a resistance connected into the primary circuit, which is cut out of circuit after a given period. This is generally cut out in one step by a contactor.

The closing of this contactor *R* is generally controlled by a timing relay *T*, as in Fig. 310. It is essential that this timing relay be kept in operating condition, for if the stator resistance is not cut out when lifting heavy load, the motor may not be able to start

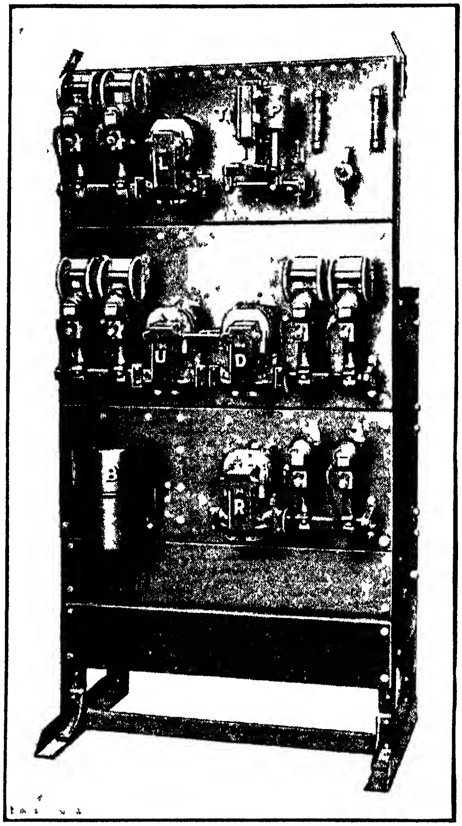


Fig. 310.—Full magnetic type controller for squirrel-cage motor starting with primary resistance

Contactor *L* is the line switch; *U* and *D*, up- and down-direction switches; *R*, contactor for short-circuiting the primary resistance; *P*, reverse-phase relay; and *T*, timing relay.

the load and when lowering a heavy load the elevator may race. When lowering a heavy load, the induction motor becomes a generator, pumps back into the line just as a direct-current motor does, and acts as a brake to keep the elevator under control. If the primary resistance is in circuit, the motors speed will have to

increase considerably above normal to supply the necessary braking current.

An open-circuit in one leg of this primary resistance would prevent the motor from starting and where a phase-failure relay is used may cause this relay to function and open the line contac-

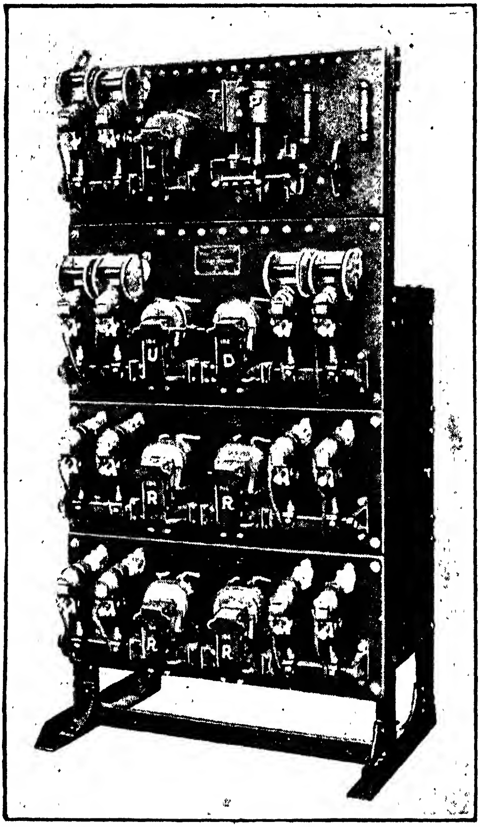


FIG. 311.—Full-magnetic type controller for wound-rotor type motor. Switches *L*, *U*, *D* and *T* are the same as for Fig. 310. Contactors *R* close and cut out the rotor resistance in four steps.

tor. If this does not occur, when the resistance contactor closes the motor will start but will probably cause an unpleasant movement of the car. These controllers may be operated either from a hand rope in the car—that is, semi-magnetic—or full magnetic, Fig. 310, operated from a car switch. Where a full-magnet type controller is used, the direction switches are magnetic contactors

controlled from the car switch as on direct-current motor controllers. What has been said in Chapter XX regarding the troubles in the direction-switch operating circuits for direct current applies to alternating-current controllers.

Wound-rotor Motors.—Another method of applying alternating-current motors to slow-speed elevators is to use a wound-rotor motor with external resistance. Figure 311 shows a full-magnetic type of controller for such a machine. The top, contactor *L* is the line switch; contactors *U* and *D* are the direction switches, the four contactors *R* are to cut out the rotor resistance in four steps and *T* is the timing relay that controls the closing of the accelerating contactors *R*. As soon as the controller is energized, the timing relay *T* closes, but is immediately released and starts to open, the time of opening being controlled by a dashpot *P*. It is necessary for this relay to open and close its contacts for the accelerating contactors *R* to close. In case of the accelerating contactors failing to function, one of the first places to look for trouble is the accelerating-relay contacts. On the other hand, if the motor is being accelerated too quickly, the relay contactor may not be closing or the dashpot may allow the relay to open too quickly.

With the wound-rotor motor the same trouble can occur in the stator circuit as in the squirrel-cage motor. In addition to this the rotor circuit is to be reckoned with. In case of the motor failing to come up to speed the rotor resistance may not be cut out of circuit or the brushes may not be making good contact on the collector rings. Under certain conditions with one phase open in the rotor, the motor will only attain about half speed and remain at that. Single-phase operation of the rotor will also cause noisy operation.

High-speed Equipments.—For car speeds above 150 to 200 ft. per minute two-speed motors are generally used. These motors may have a single winding in the stator which is regrouped for one-half and full speed such as 450 and 900 r.p.m. Instead of using a single winding, two windings may be used in the same stator. With this arrangement most any ratio of speed can be obtained up to 1 to 6. For example, one winding would give a theoretical speed of 200 and the other 1,200 r.p.m. Instead of using a single motor, two are frequently used in tandem. Two stators are placed in a single frame and two rotors are keyed to the same shaft. One of the stators is wound for slow speed and

the other for high. In general only a squirrel-cage type of rotor is used, but in some installations the high-speed machine has a wound rotor, connected to external resistance. There are two methods of starting these motors: (1) on the low-speed winding and then switch to the high-speed, Fig. 312; (2) all the starting is

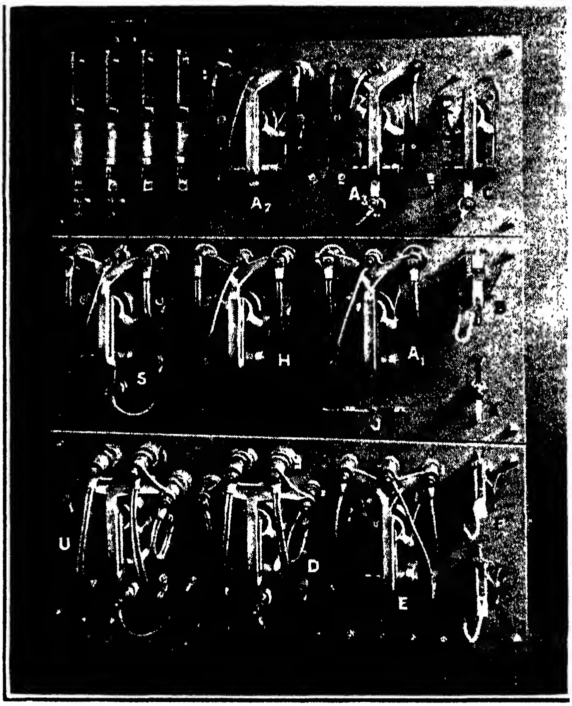


FIG. 312.—Full-magnetic type controller for two-speed double-winding squirrel-cage motor.

Contactors *U* and *D* are the up- and down-direction switches; *E*, buffer-restistance contactor; *F*, up direction-switch interlock; *G*, down direction-switch interlock; A_1, A_2 and A_3, accelerating contactors; *H* and *S*, high-speed and slow-speed contactors; *B*, high-speed interlock; *C*, speed-change interlock; *J*, control throw-over switch; and *K*, control switch.

done on the high-speed winding. In either case the slow-speed machine is switched in during the stopping period to slow the machine down before disconnecting from the line and applying the brake to stop the machine. Except that control is provided for two motors instead of one and sometimes a governor-operated switch is provided to hold the slow-speed motor's contact in after the high-speed motor has been cut out, until the elevator has

slowed down, the control for these equipments does not offer any difficulties not found with other types of full-magnet type controller. With these equipments, if trouble is being experienced with the brake running hot or not stopping the car quickly enough, it should be made sure that the slow-speed motor is being cut into service during the stopping period. If this is not done, all the work of stopping the elevator from high speed will have to be done on the mechanical brake and may result in unsatisfactory operation.

CHAPTER XXII

LUBRICATION

General Considerations.—The problem of elevator lubrication will vary with the type of machine and the conditions under which the equipment operates. On drum type machines, the lubrication of the worm gear is an important factor in its successful operation, where with the direct traction type the worm gear does not come into the picture. Broadly, lubrication of elevator equipment may be divided into cables, worm gear, guide rails, sheaves, motor and other bearings and wearing parts.

Lubrication of Cables.—Contrary to the general idea a wire rope is a complex mechanism, composed of a number of wires twisted to form a strand, and then a number of these strands are twisted about a hemp center to form the rope. The combinations of number of wires per strand and the number of strands in a rope are practically unlimited. There are on the market about seventy of these combinations, but for elevator service 6 strands of 19 wires each has become the type that is generally used.

In elevator service the cables bend over sheaves, and while the car is in motion parts of the cable are continuously bending and straightening out again. This operation causes a continuous rubbing of the wires and strands upon each other. These rubbing surfaces, like any other, require lubrication. When the rope is made, the hemp center is thoroughly saturated with lubrication and if not installed in a damp place this will furnish sufficient lubrication for the cable for a considerable period.

There is considerable difference of opinion with regard to the application of external lubrication, but it has been proved by tests that internal friction in the cable increases bending stresses that cause wires to break. This fact alone should be sufficient to warrant lubrication of elevator cables. Where the wires on the outside break, they can be seen and detected before the cable gets in a dangerous condition. However, when the inside wires break, as they sometimes do owing to lack of lubrication, the rope may reach the danger point without giving external evidence.

Ropes operating in vapor, fumes or in damp places will rust and corrode unless they are kept lubricated.

There seems to be little reason for not lubricating elevator cables when the advantages are weighed against the objections. About the most serious objection is that of the extra work and the care that must be exercised to prevent the lubricant dropping into the car. A good non-acid, medium-heavy oil that will penetrate to the core and also stick to the surface is desirable. There is not much value in a lubricant that is so thin that it will run easily and drip from the rope. On the other hand, it should not be so thick and sticky that it will not penetrate into the hemp center. A number of elevator manufacturers have for sale lubricants that they recommend for this purpose. Experiments have proved that a non-acid lubricant having a Saybolt viscosity of from 1,000 to 2,000 sec. at 210 deg. is well suited for this purpose.

Some authorities claim that where the cables are in a warm, dry place and in use less than three years and run over generous-sized drums and sheaves, there is sufficient lubrication in the cable to prevent abrasion of the wires and strands on each other. If the life of the cables exceeds this period or when they travel over small sheaves or drums, frequent lubrication is necessary, particularly in cold, damp places. The best practice will be found to watch the cables carefully and to apply lubrication if they show signs of being dry or rusting. Even in dry places it will be found good practice to apply lubrication at least once every six months and every three months under the more severe conditions.

There are a number of ways of applying the lubricant to the cables. One is to paint it on with a brush. The best method is to make a split box that will fit around the cable and apply the lubricant hot while the cable runs through it in the box. In this way the entire surface of the cable is covered with a thin film of oil.

Worm and Gears.—Lubrication of the worm gear on drum-type machines and on geared-type traction machines requires careful consideration. In this service there are rubbing surfaces under heavy pressure that are at one instant in contact and at the next are relieved of the load. In some applications ball or roller guide and thrust bearings are used on the worm shaft, where in others, sleeve guide bearings and disk thrust bearings

are used. In still other applications a combination of the two types of bearings may be used.

The kind of oil to use in the gear case is a moot question, but it is generally agreed that it must have sufficient body to stand the heavy pressure it is subjected to on the gear teeth without

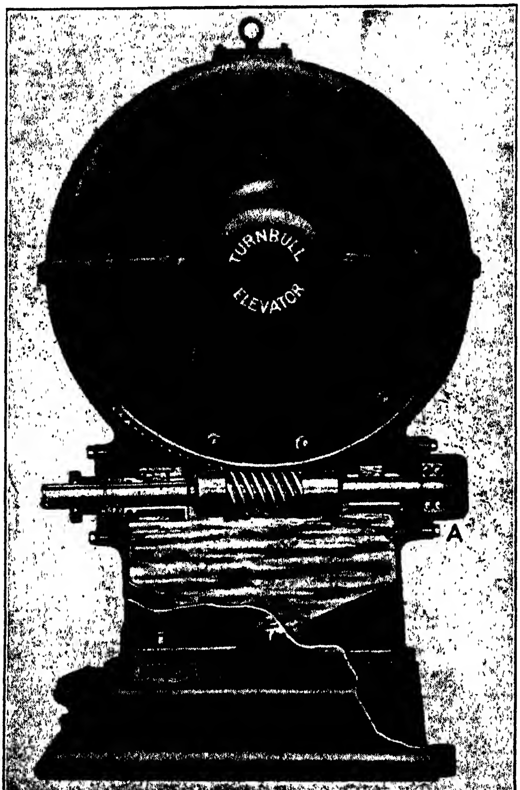


Fig. 313.—Section through worm and gear showing oil level and thrust bearing.

allowing metal-to-metal contact with the worm. It should also be free from alkalies and acids. This is particularly true where ball or roller bearings are used, since their service efficiency is seriously impaired by even slight pitting of their surfaces. Elevators are frequently situated where they are subjected to wide range of temperature, from the intense heat of summer to the lowest temperature of winter. In such cases it is important

that the oil should not be seriously affected by a change in temperature.

Successful lubrication of worm gears has been accomplished with a straight mineral oil such as a high-grade steam-cylinder stock having a flash point around 600 deg. F. and a viscosity of

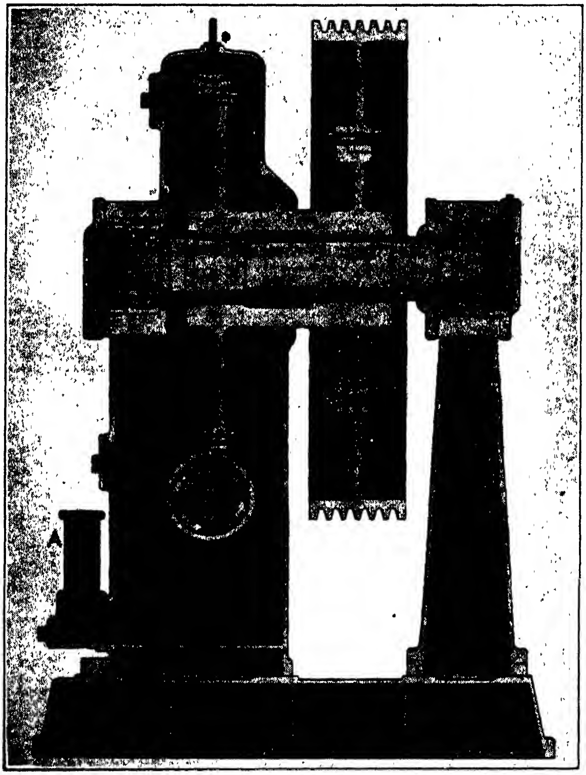


FIG. 314.—Cross-section through V-grooved, geared type traction machine.

about 150 sec. Saybolt at 210 deg. F. Other recommendations are for a straight mineral oil having a viscosity of about 120 sec. at 210 deg.,[1] but with a pour test much lower than cylinder stock. Oil containing such fillers as graphite has been used. Then, again, castor oil has many advocates, and as high as 50 per cent castor has been used in worm-gear lubricants. Where castor oil is mixed with a straight mineral oil, there is always the danger

[1] Modern Elevators, *Lubrication* August, 1922.

that they will separate in the gear case. This can be prevented if the oils are properly compounded, but it will probably require the use of a third component. In view of this wide variation of opinion it will be well to consult the elevator manufacturer or the engineers of a responsible lubrication company if trouble is experienced with the problem. Most elevator manufacturers have lubricants that they recommend for use in the gear cases of their machines.

There is an idea among many maintenance men that the higher the oil is kept in the gear case without running out, the better the worm and gear is lubricated. This is absolutely wrong. Under these conditions the gear acts as a pump and no only greatly increases the power consumption for operating the machine, but also tends to heat the oil, and in addition it works out of the gear case and creates a dirty condition around the machine. For best lubrication of the worm and gear the oil level should not come above the center line of the worm shaft, and some manufacturers arrange their machines so that the lower side of the worm dips into the oil only, as shown in Fig. 313, which is a section through a Turnbull Elevator Co.'s gear for use on machines operating at car speeds up to 500 ft. per min. The worm in this machine has seven threads. To prevent too much oil being put into the gear case, an overflow of large dimensions is provided, as shown at *A*, Fig. 314. This overflow also provides a means of determining the amount of oil in the gear case.

Preventing Cutting of Worm Gears.—Owing to the absence of lubricant or to using an improper quality, the worm and gear may start to cut. This action is made evident by a loud grinding noise in the gear case and heating of the worm and gear, accompanied in many cases with vibration in the machine. The grinding noise, however, should not be confused with that which occurs when a ball thrust bearing is in bad condition due to chipped balls or races. To stop the cutting of a worm and gear, put about one pound of sulphur in the gear case with the oil and operate the machine until the gear teeth take a smooth polished surface. Under ordinary conditions this will require about 8-hours operation. If the elevator is used only intermittently, a longer period of operation will be required. After the worm and gear are in condition, drain the oil and wash out the gear case with kerosene, being sure that it is thoroughly cleaned out before putting in new oil.

Motor Bearings and Other Parts.—For the motor bearings and other parts, outside of slow-moving sheaves equipped with mill-type babbitt bearings, a good grade of motor oil will generally meet the requirements. On slow-moving sheaves carrying heavy loads, a heavy oil or grease is generally used, depending upon the method of applying the lubricant.

When lubricating the elevator equipment, the safeties under the car should not be overlooked. These parts, in normal operation, are seldom called upon to operate, but when they are it is generally in an emergency, and they should be kept in good working condition and should not be allowed to rust and become inoperative through lack of attention and lubrication.

When purchasing and applying lubricants, it should be remembered that a good oil properly applied is the cheapest kind of maintenance. Buying a lubricant because it is cheap, is false economy.

Lubrication of Guide-rails.[1]—Lubrication of guide rails is the most difficult problem connected with passenger- and freight-elevator operation. The lubricated surfaces of the rails are exposed and collect dust and dirt blown about by the car as it passes up and down the hoistway. In modern high buildings the rails may be 1,000 ft. or more in length, with cars operating at speeds up to 1,200 ft. per min. High rises and high speed add materially to the difficulties of maintaining a good film of lubricant on the rail surfaces.

If the oil film becomes too thin or broken, the guide shoes will bite the rails and cause noise and unpleasant riding of the car. Wear of the guide shoes, power consumption for the elevator's operation, and maintenance costs will increase. When there is an excess of lubricant on the rails, it is thrown off by the guide shoes into the car and into the bottom of the hoistway. If oil gets on the car, it is likely to work inside of the cab and cause stains, or worse, get on passengers' clothing. In addition it creates a dirty condition in the hoistway and adds to the difficulties of keeping the place clean.

Manual Lubrication.—The old method of lubricating guide rails is to paint them with a heavy oil or grease periodically, the operation being performed by an attendant riding on top of the car.

[1] Acknowledgment is hereby made for assistance in the preparation of this chapter to the Atlas Elevator Devices Co., Albert Johnson, Otis Elevator Co., Elevator Supplies Co., Inc., Westinghouse Electric Elevator Co., Yvan Zenon, Bowman, Agency, Inc., A. B. See Elevator Co., O K Lubricator Co., and J. C. Edgecumbe Co.

Lubrication of guide rails by hand is about the most hazardous and disagreeable job in the maintenance of elevators. Not only are the services of two men required to do the job, one to operate the car and another to ride on top and do the greasing, but the elevator must be taken out of service while the work is done. For these reasons, where lubricating is done by hand, it is frequently neglected.

Another objection to hand greasing is that the rails either have a feast or a famine of lubricant. There is generally too much grease on the rails when the lubricating is completed. After the elevator has operated awhile there is a deficiency of lubrication, and the rails may not be greased again until attention is called to the need by the guide shoes seizing the rails.

Automatic Guide-rail Lubrication.—In an attempt to overcome these difficulties, automatic lubrication of guide rails has come into general use. Automatic lubrication of guide rails is by no means a simple problem, as evidenced by the large number of devices that have been developed for this work. Some of these have been satisfactory on low-rise slow-speed cars and failed to meet the requirements of high speed and high rises. Others have not been entirely satisfactory for other reasons. There are several types available that give satisfactory operation if used for the conditions for which they are suited.

Lubricants ranging in consistency from light oil to solid greases are used in automatic lubricators. One of the advantages claimed for light oils is that they tend to run down the rail and wash the dust and dirt off. On the other hand, at high speeds they are more likely to be thrown off the rails by the guide shoes. This difficulty can be at least partly overcome by chamfering the top and bottom edges of the guide-shoe gibs, so as to form receptacles for the oil. Greases, although they adhere to the rails better than oils, have the corresponding disadvantage of holdng any dirt that may be deposited on the rails.

Stationary-type Automatic Lubrications.—Automatic guide-rail lubricators are made in two general types: those that are stationary and are mounted at the top of the hoistway, and those that are located on the car and counterweights and travel with them. The stationary types generally use oil as the lubricant. Since they are mounted at the upper end of the guide rail, it is necessary that the oil be of the right consistency to run down the rail and assist the guide shoes in its distribution.

One type of stationary lubricator is shown in Fig. 315. It consists of a reservoir from which oil is fed continuously by three wicks to three sides of the guide rails. A spring *A* passes down the center of a tube and comes out on the guide rail as indicated at *B*, there being three tubes, one for each side of the rail. About halfway down each spring is a loop *C*, through which the wick passes and doubles back into the oil in the reservoir. The amount of oil fed to the guide rails is controlled by the number of wicks looped through the springs.

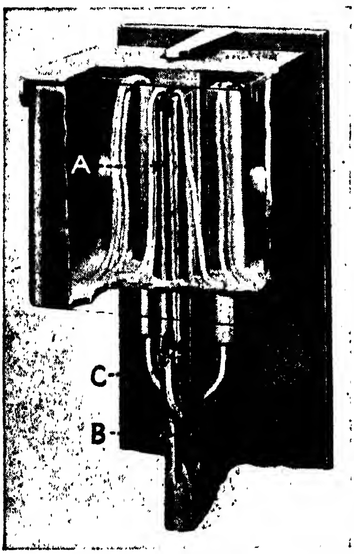


FIG. 315.—Wick-type stationary lubricator.

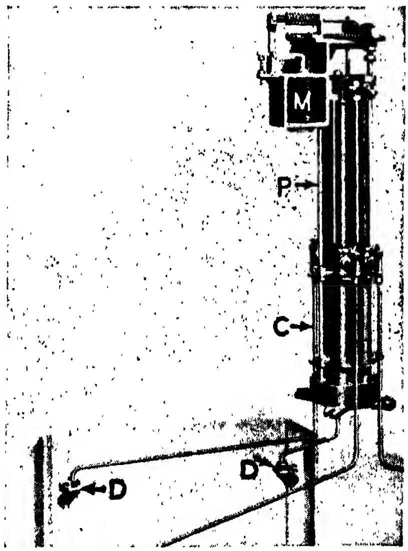


FIG. 316.—Positive-type stationary lubricator.

One of the most desirable locations for these lubricators is on the top ends of the guide rails when they have been extended up into the pent house. If not installed in this manner they may be mounted on a short section of guide rail in the elevator-machine room and the lubricating tubes extended down to the top ends of the guide rails.

A type of stationary lubricator using a common reservoir for the four guide rails is shown in Fig. 317. Oil is fed from the reservoir by capillary action of wicks *W* that dip into the oil and pass into the conveyor tubes that lead to a U-shaped element *E* fastened near the top end of each guide rail. These elements have three wicks that distribute the oil evenly to the three sides

of the rails. To maintain a constant oil feed from the reservoir to the guide rails, the capillary elements are mounted on a float *F* that rises and falls with the oil level in the reservoir. The wicks lead into tubes *T* supported on the float. These tubes telescope into tubes *T′* with a clearance that allows a free movement of the float. Since the float maintains practically a constant length of wick in the oil at all levels of the lubricant, the capillary action is constant and oil feed uniform. Adjustment of rate of oil feed can be made by raising or lowering tubes *T*, which are held in their supporting brackets by setscrews.

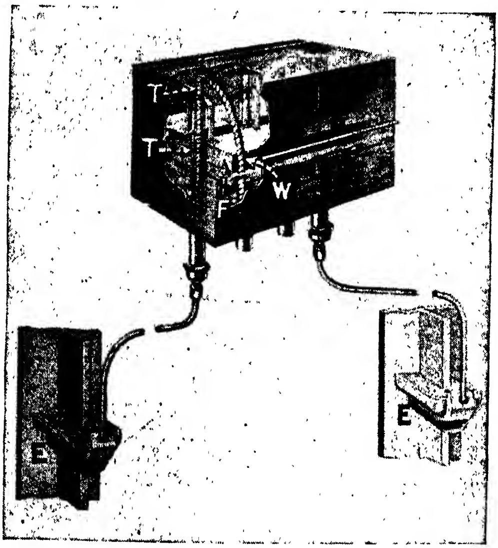


Fig. 317.—Reservoir-type stationary lubricator.

The two types of lubricators just described supply oil to the guide rails when the car is not in operation just as when it is in service. This may be objectionable if the car is shut down for long periods. Figure 316 shows a type of lubricator that feeds to the rails only when the car is in operation. This device is electrically operated, is placed in the pent house and as a unit automatically lubricates the four guide rails. Oil contained in four cylinders, one for each guide rail, is forced out by the downward motion of pistons *P*. After being forced out of the cylinders, the oil flows by gravity through tubes to the distributors *D*, which deliver it to the three surfaces of the rails. Magnet *M* is energized by the car closing a hoistway switch or by a

contact on the selector switch. When this coil is energized, it works a ratchet that turns a threaded shaft to lower the plungers into the cylinders. The stroke of the plungers is adjustable so that the amount of oil delivered to the guide rails each time the magnet switch is closed can be made proportional to the installation's requirements.

Traveling-type Automatic Lubricators.—Several traveling types of automatic lubricators are mounted on the car and counterweight guide shoes. One of these, operating on a siphon

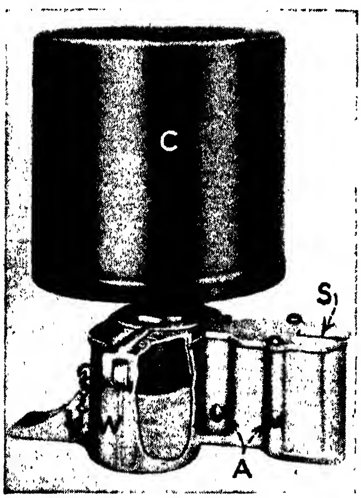


FIG. 318.—Siphon-type traveling lubricator.

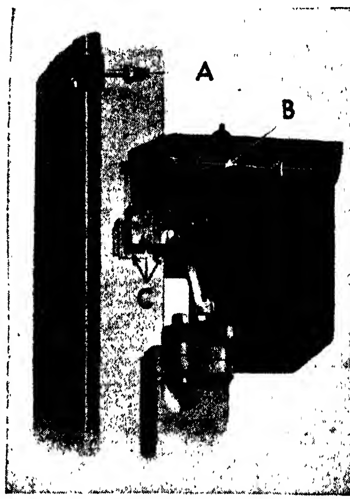


FIG. 319.—Positive-type traveling lubricator.

principle, is shown in Fig. 318. This lubricator is designed to apply a heavy oil uniformly to the guide rails. A nipple threaded through the cover of the oil well *W* supports the oil container *C*. By turning the container the lower end of the nipple is raised or lowered into the oil well and the oil level thus adjusted to obtain the proper feed to the rail for satisfactory lubrication.

The lubricator is supported on top of the guide shoe so that the guide rail passes through the slot *S*. A felt wiper contacts the rail on three sides and siphons the oil from the well and distributes it on the rail's surfaces. Oil is fed to the rails only when the car is in motion. Any wear on the felt wipers may be taken off by turning adjusting screws *A*.

Another type of lubricator for applying a heavy oil to the guide rails is shown in Fig. 319. The oil is fed from a reservoir by a

mechanically operated pump. The lubricator is mounted on top of the car or counterweight guide shoes. As the car starts from the terminal floor, lever *B* strikes a contact arm *A*, fastened to the guide rail, and causes the lever to move downward. This action operates the plunger of a pump in the oil reservoir and a charge of lubricant is delivered to an auxiliary reservoir from which it drips to fiber distributing blocks *C*. These are held in contact with the rail, and spread the oil uniformly as the car travels up and down the hoistway. A heavy oil is used in this type of lubricator and the quantity may be adjusted to suit the service conditions.

Inertia-type Lubricators.—The type of lubricator shown in Fig. 320 operates on the inertia principle and is designed to apply a grease to the guide rails. The gun, which will develop approximately 40-lb. gage pressure, forces a special grease out through a flexible tube to a distributor mounted directly above the guide shoe. The lubricator consists of two parts and is mounted on the car or counterweight crosshead. The upper part compresses a housing with a movable cap, the driving mechanism, and a piston with its feed shaft. The lower part is a grease container of proper size to receive the piston. The weighted lubricator cap is balanced by an adjustable spiral spring, so that it floats on its bearings sensitive to changes in acceleration.

When the elevator is started or stopped, the cap rocks up and down from its inertia. This movement is transmitted in a positive direction to a driving wheel. The wheel in turning drives a wormshaft which is geared to the piston's feed shaft. The distance through which the lubricator's cap can swing each time the car starts and stops is controlled by an adjustable buffer, which permits regulating grease to the guide rail.

Another inertia type of lubricator is shown in Fig. 321. This type uses oil pumped to an auxiliary reservoir from which it flows to rail under close regulation. *P* is an inertia-type pump operated by weight *W*, supported on spring *S*. Any sudden car movement, such as start or stop, causes the weight to move up and down and operate the pump: Oil is delivered through pipe *B*, into groove *G* leading to three chamber openings *O*, one for each wearing surface of the guide shoe. Each chamber *O* is filled with cut felt to absorb and retain oil. Wire conductors *C* at the bottom of each chamber carry oil out and deliver it in drops to a groove adjacent to rail *R* around the top of the guide shoe *D*.

The oil flow to the rail is regulated by changing compression on retarding felts with adjusting screws *A*. Any surplus oil

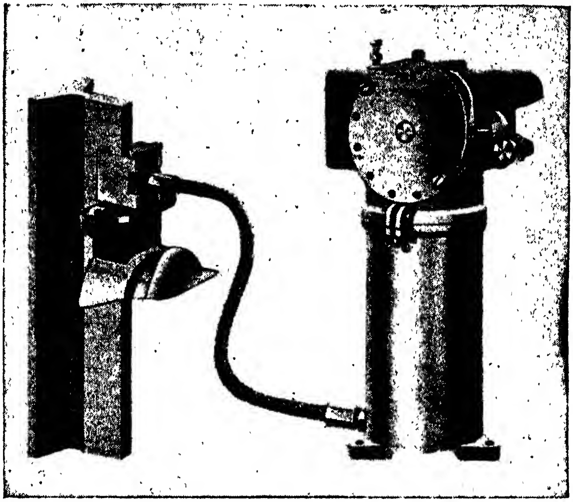


FIG. 320.—Inertia-type, traveling, multiple-grease lubricator.

delivered to groove *G* is returned to the reservoir through an overflow. The quantity of oil pumped can also be regulated by adjusting the pump stroke. Each lubricator has a capacity of

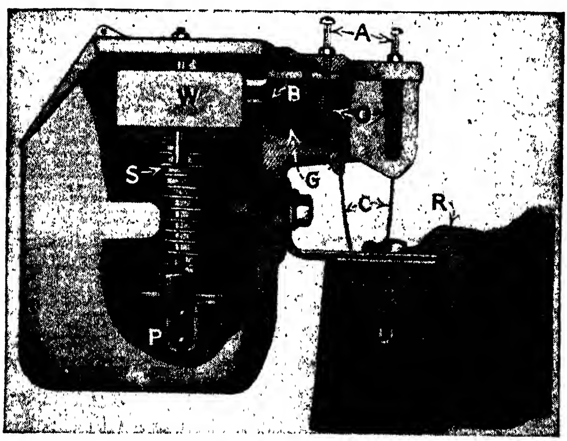
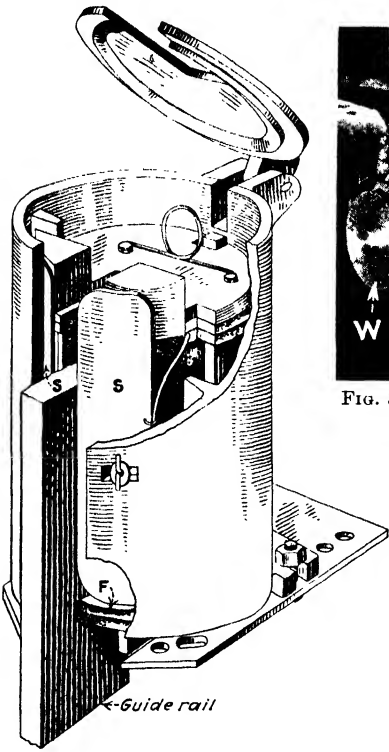


FIG. 321.—Inertia-type, traveling, individual-oil lubricator.

three pints, sufficient to last several weeks with regulated flow of one drop per guide face per round trip for moderate high-rise, high-speed cars.

Grease Lubricators.—In the design in Fig. 322, the guide rail passes through the grease reservoir, which is mounted on the guide shoe. The bottom of the reservoir is sealed to the guide rail by a felt pad *F*. On top of the grease is a weighted pad. The front of the reservoir is sealed to the guide rail with two spring-actuated fiber shutters *S*. Recommended for use in these



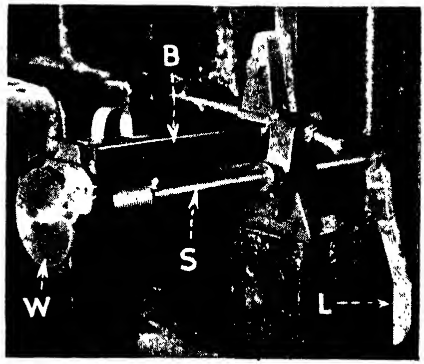


Fig. 323.—Positive-feed-type grease lubricator.

Fig. 322.—Traveling grease-type lubricator.

lubricators is a light-weight grease which is packed in the reservoirs around the guide rails and is applied to them by movement of the car and counterweights. Lubricant is applied only when the car is in motion, the action being much the same as if the grease were applied by a soft brush rubbing on the rail.

The lubricator in Fig. 323 is of the force-feed type and uses a special high-grade grease in stick form. The grease stick is put into the barrel *B* and is forced out onto the rail by a metal block that is pushed ahead by a feed screw. The grease is applied to the rail by a fiber shoe that is supported in a pivoted carrier.

A wheel *W* on one end of the feed screw is turned by a ratchet through the motion of shaft *S*, upon which is supported operating lever *L*. A small cam is mounted at the top or bottom end of the guide rail. The car approaching the end of travel comes in contact with the operating lever, and moves the ratchet wheel and feed screw to supply a small amount of lubricant to the guide rail. The amount of grease fed to the guide rail may be regulated by an adjusting screw to limit the throw of the operating lever.

The guide-rail lubricators described in the foregoing do not include all the designs that have been developed and used. They are, however, representative of the different principles that have been employed in that class of equipment.

Guide-shoe Gibs.—Guide-shoe gibs are an important factor in guide-rail lubrication and smooth car riding. Early guide shoes were cast iron, unlined, and bolted solidly to the car. Later they were babbitted, made adjustable, and held to the rail by spring tension, a standard method of fastening even today. But materials have become much more diversified, varying with conditions through cast iron, oil-impregnated wood, wood with babbitt inserts, horn fiber, horn fiber with lubricating compound inserts, Bakelite or other molded products with canvas base (such as Malikite, etc.), Malikite, fiber, or wood faced with steel, bronze, nickel-copper alloy, and other metals.

Fibrous materials, such as wood or Malikite, improve car-riding qualities and better guide-rail lubrication. Oil-impregnated maplewood gibs have these qualities in high degree but lack wearing strength and may split under severe operating conditions. Holes filled with babbitt on their inner surfaces improve their wearing qualities. These gibs, like most non-metallic types, are made in three parts, two sides being dowelled to a back. Horn-fiber gibs, are usually similar in design to wood gibs but do not have babbit inserts because the wearing qualities of fiber are about equal to those of babbit.

Malikite gibs are similar in construction, but have face inserts of lubricating-compound. Malikite is a tough, resilient molded product with canvas base, therefore is not easily broken, chipped, or cracked in service. Its inherent quasi-lubricating qualities produce a highly glazed surface from constant rubbing on the rail, augmented by the grease inserts. For slow- and medium-speed cars operating on good rails, these gibs are practically self-lubricating.

This property is utilized in several large buildings in which guide rails are lubricated only at long intervals. Further, the holes on the rubbing surfaces have a tendency to pick up grease where there is an excess and to redistribute it where there is a deficiency. Recesses are cut into the gib ends into which grease may be packed at intervals to assist in lubrication.

With high-speed cars, however, it is necessary to lubricate guide rails with this type gib just as with other types, except that the non-metallic gib is less likely to "bite" a dry guide rail than is its metallic prototype, thereby simplifying the lubrication problem. Malikite three-part metal-lined gibs held to the rail surface by flat springs extending their full length are also used. Each gib section has a back recess into which the spring fits. Metallic wearing surfaces give it good wearing qualities, while the non-metallic body and springs give it resiliency that tends to keep noise and "rough-riding" from reaching the car, even in high-speed service. Also, with three-part construction, any worn part can be replaced without replacing the entire gib.

Before any type of gib will operate successfully, not only must rails be in alignment but their surfaces and joints between must be smooth. Rails can be surfaced by putting cast-iron gibs in the guide shoe and lubricating the rails with a mixture of sulphur and oil. The car is run until the rails attain a good surface, then rails are cleaned thoroughly with kerosene, the guide-shoe gibs are replaced, the rails lubricated with the regular lubricant, and operation started on normal schedule.

If the car does not hang in good balance between the rails, parts of the guide shoes will wear more rapidly than they should. Several ways of attaching car and hoisting ropes, particularly automatic rope equalizers, provide a method of shifting car balance so that it hangs true.

Life obtained from a set of gibs varies widely with conditions. Under good operating conditions, either metallic or non-metallic gibs of the Malikite type will give 30,000 car miles or more service. Fiber will in general have shorter life; wood usually is not as good as fiber. On the other hand, the cost of gibs of the various materials varies about in proportion to wearing quality, so the most economical material must be selected to suit the particular job.

CHAPTER XXIII

ROPES, THEIR CONSTRUCTION, INSPECTION, AND CARE[1]

Metals Used in Wire Rope.—Wire rope is an important part of electric elevator equipment. It connects the car and counterweights with the hoisting machine and overspeed governor to the car safety devices. Therefore the car's operation and safety of passengers depend upon wire rope. For this reason those responsible for elevator operation should be familiar with wire-rope constructions and factors affecting its service and safety.

Wire rope is made in a great variety of forms and of many materials. Although generally made of some grade of iron or steel, Monel metal, bronze, and other metals are used for special conditions. For example, Monel-metal rope is a non-corrosive type, suited for wet places, as in meat-packing houses or where chemical fumes or salt in the atmosphere would destroy iron or steel rope.

The material used in so-called iron rope is a very mild steel, containing about 0.1 per cent carbon. It is comparatively soft, ductile, and of low tensile strength. Wire of this material for rope construction has a tensile strength of about 85,000 lb. per sq. in.

What is known as traction steel, a form of toughened mild steel containing about 0.35 per cent carbon, is used extensively for traction-type elevator ropes. This material has a tensile strength in the wire of about 150,000 to 170,000 lb. per sq. in. Cast steel, the first of the so-called higher-carbon steels and frequently called crucible steel, is another common material used in wire-rope construction. It is one of the most ductile of the high-carbon steels, having a tensile strength in the wire of from 170,000 to 220,000 lb. per sq. in. Three other steels, designated as mild-plow, plow, and improved-plow are in common use for

[1] For assistance in the preparation of this article the author is indebted to the American Cable Co., the American Wire & Steel Co., John A. Roebling's Sons Co., Hazard Wire Rope Co., A. Leschen & Sons Rope Co., Williamsport Wire Rope Co., Broderick & Bascom Rope Co. and the MacWhyte Wire Rope Co.

wire-rope construction. They have a tensile strength in the wire of about 220,000 to 280,000 lb. per sq. in. These and others, appearing under various trade names, are mostly some form of open-hearth steel.

Of the various materials for wire rope construction, iron and mild steel are about the only ones used for elevator ropes. Mild-steel ropes frequently appear under the trade name of traction steel or other designations.

Wire-rope Applications.—The ideal rope would have great strength and stand a large amount of bending without fatigue and breaking of individual wires. Under the present state of the steel-making art it is impossible to obtain the maximum of these two qualities in the same rope. The higher the strength given the wire, the harder and more brittle it is. Although plow-quality steels have great strength, they lack the necessary ductility for elevator service. These higher-carbon steels have a wide range of use in mining duty, logging lines, excavating machinery, dredges, heavy cranes, and similar applications.

Rope Constructions.—After the wire has been drawn to size and heat-treated to give it the desired qualities, it is ready to be formed into rope. Rope-making consists of twisting a given number of wires into a strand and laying a number of these strands about a hemp center. In some cases, for use on dead loads, disk conveyors and hot-metal cranes, a wire center is used. Tiller rope and mooring line have strands made with hemp centers. In general the strands are laid around a central wire, although in some constructions they have centers of special forms.

Combinations of wires and their sizes in a strand and number of strands in a rope are almost unlimited. There are on the market about eighty different constructions varying from three to ninety-one wires in a strand and from three to nineteen strands in the completed rope. Only a few of these constructions are in general use for elevator service.

A common hoisting-rope construction is one that has six strands of nineteen wires per strand, known as the 6×19 construction, Fig. 324. Each strand has a central wire about which is placed a layer of six wires. Outside the six-wire layer is another of twelve wires, both layers being twisted in the same direction. The rope is formed by laying six of these strands about a hemp center, as in the figure.

Another common construction has six strands of thirty-seven wires each. Where the wires in the strands are all approximately the same size, the construction is the same as for the nineteen-wire strand, but with a third layer of eighteen wires. This is the highest number of wires per strand used for elevator-hoisting ropes.

For certain purposes where a very flexible rope is required, sixty-one and ninety-one wires per strand have been used. The sixty-one-wire strand is obtained by adding a layer of twenty-four wires over a thirty-seven-wire construction. Adding a

Fig. 324.—Regular 6 × 19 wire-rope construction.

Fig. 325.—Strand construction, ranging from 7 to 91 wires.

thirty-wire layer over the sixty-one-wire construction produces the ninety-one-wire strand. These various constructions are shown in Fig. 325. The greater the number of wires per strand for a given size rope, the smaller the individual wires will be in cross-section.

Except for hawsers, mooring lines, and guys, few wire ropes are made with all wires the same size. Even when the wires may appear to be the same size, as in the 6 × 19 regular constructions, the inner ones are slightly larger than the outside ones. This difference in size is necessary in a rope of this kind, to obtain a construction that will stand bending and retain the original arrangement of the wires in the strands.

Another rope used for elevator service has eight strands of nineteen wires each. Although this construction is more flexible than 6 × 19, it is not so strong for equal diameter. To get eight

strands within the same diameter, each strand must have a smaller diameter than when six are used. The strands in the 8 × 19 construction being smaller than for the 6 × 19, the hemp center is large, consequently the eight-strand rope has less metal and strength than the six-strand construction. For example, the breaking strength of a $\frac{5}{8}$-in. 6 × 19 cast-steel rope is about 25,000 lb., whereas a $\frac{5}{8}$-in. 6 × 19 rope of the same quality will break at about 22,000 lb.

Warrington Construction.—Figure 327 shows the cross-sections of various rope constructions used in elevator service. *A* and *B* are the regular 6 × 19 and 8 × 19 types, respectively. All wires in either of these are approximately the same size. Constructions *C* and *D* have three sizes of wire. The seven inside wires

FIG. 326.—Flattened-strand rope construction with elliptical-ribbon center.

are approximately the same diameter and are surrounded by twelve that are alternate large and small, a construction known as "Warrington." Experience has shown *C* and *D* to be satisfactory constructions, and they are used extensively.

Where bending stresses are severe, the 6 × 37 construction, shown at *E*, is sometimes used. Each strand is made of 37 wires of approximately the same size and six strands are laid about a hemp center to form a rope. Since the wires are small, the rope is not suited to conditions where wear is an important factor in its life.

Seale Construction.—Another construction, used for elevator hoisting ropes, is known as Seale; three different combinations, *F*, *G*, and *H*, being shown in Fig. 327. The 6 × 19 Seale construction has one large center wire surrounded by nine small ones, around which are nine large wires. This construction will, for many conditions, stand more wear than constructions *A* and *C*. The rope is somewhat stiffer than the other constructions and is not suited for use on small sheaves or where it would be subjected to short reverse bends.

The 6 × 27 Seale construction *G*, Fig. 327, has seven small wires in the center of each strand, with ten small wires and ten

larger ones laid over the seven center wires. This is a more flexible construction than obtained with the 6 × 19 Seale.

At *H* is shown an 8 × 19 Seale construction. The strands in this rope are made the same as for the 6 × 19, but with smaller wires. The 8 × 19 construction is more flexible than those shown at *F* and *G*, but it has less metallic cross-sectional area and tensile strength. The Seale construction is such that the crowns of the inside wires fit into the valleys between the outside wires. This allows a close construction of the strands, resulting

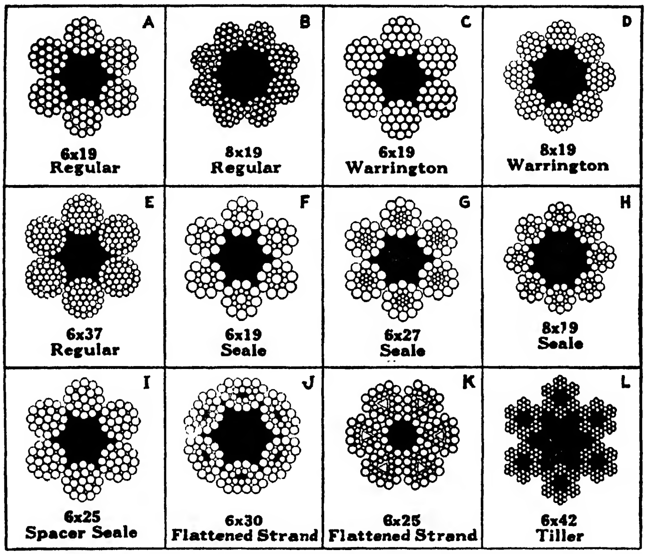


FIG. 327.—Cross-sectional arrangements of different types of wire rope.

in an increased metallic cross-sectional area and strength. The 8 × 19 rope has superior bending qualities compared to those of the 6 × 19 construction. Where ropes are subjected to reverse bends, the 8 × 19 is, in many cases, preferable to 6 × 19 construction.

Another Seale construction is known as spacer Seale, a 6 × 25 section being shown in Fig. 327 *I*. This construction has six wires twisted around a center wire, all wires being approximately the same size. Six small spacer wires are placed in the valleys between the six large wires laid around the center. Over these are laid twelve wires of approximately the same size as the center ones. The six small spacer wires act as keys to maintain a fixed relation between the outside and inside wires in the strand.

Flattened-strand Construction.—To obtain a rope with large wearing surface, a flattened-strand construction is sometimes used. Two types of these are shown in Figs. 327 *J* and *K*. The center of the strand, construction *J*, is made of nine small wires arranged to form an ellipse. About this center are laid nine larger wires over which is placed a layer of twelve wires. These wires are slightly larger in diameter than used in regular 6 × 19-rope construction. This rope has a larger wearing surface than ordinary types and is more flexible than the regular 6 × 19 construction.

Another flattened-strand construction, somewhat similar to *J*, has an elliptical ribbon center, Fig. 326, but is not as flexible.

Triangular-strand Construction.—In the construction Fig. 327 *K* the strands are made of a triangular center wire about which are twisted twelve small wires. Over these are laid twelve larger wires. This gives a strand having a form approximating an equilateral triangle. Six of these strands are laid about the usual hemp center to form a rope. These flattened-strand constructions have about 50 per cent more wearing surface than round-strand rope and *K* is stronger than round-strand types of the same materials.

Tiller Rope.—Where a very flexible type is required, such as for the operating rope on hand-operated cars, what is known as tiller rope is used, Fig. 327 *L*. This has six strands, each constructed like a 6 × 7 hemp-center rope. These strands are laid about a hemp center, making a very flexible arrangement, but its strength is only about one-half that of the other constructions.

Regular and Lang Lay.—Numbers and sizes of wires, their arrangement in the strands, and the number of strands tell only a part of the story of a rope's construction. The way the strands are laid to form the rope must also be known. There are two lays, regular and Lang. These lays may be either left or right. A right-lay regular-lay rope is shown in Fig. 328 *A*. In this construction the strands are laid to give the appearance of a long-pitch right-hand thread on a bolt. A nut threaded to fit the pitch of the lay could be threaded onto the rope by turning it in a clockwise, or right-hand, direction. What has been said regarding a right-lay regular-lay rope applies to a left-lay regular-lay, Fig. 328 *B*, except everything is left-handed. Lang-lay rope can be obtained in either right or left lay, as shown in Figs. 328 *C* and *D*.

Regular-lay rope has the strands twisted in an opposite direction to the rope lay. For example, in the right regular-lay rope, Fig. 328 *A*, the strands are twisted in a clockwise direction, but the rope has a counterclockwise twist. In a Lang lay the strand and rope twist are the same as *C* and *D*, Fig. 328. A right Lang lay *C* has the strands and the rope twisted in a counterclockwise direction. In a regular-lay rope the outside wires on the strands run almost parallel with the axis of the rope, but in a Lang lay these wires tend to follow around the rope with the strand.

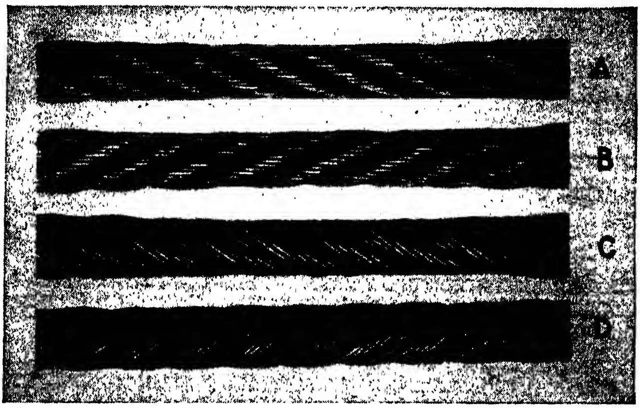


Fig. 328.—Rope lays in general use.

A, regular-lay, right-lay; *B*, regular-lay, left-lay; *C*, Lang-lay, right-lay; *D*, Lang-lay, left-lay.

These characteristics are clearly seen by comparing *A* and *B* with *C* and *D*, Fig. 328.

Lang-lay rope is more difficult to handle than regular lay, as it has a greater tendency to unstrand. It is also more easily kinked and bird-caged than regular-lay rope. For these reasons Lang-lay rope has not been used extensively. It is, however, more flexible than regular-lay rope, and the outside wires on the strands present a greater wearing surface than in regular lay, as can be seen by comparing Figs. 329 and 330. Most all flattened-strand ropes are Lang lay, such as in Fig. 326. A worn flattened-strand rope is shown in Fig. 331, which indicates its large wearing surface.

Preformed Rope.—Wire rope, as ordinarily constructed, has a tendency to unlay unless it is seized at the ends to prevent the strands untwisting. There is on the market wire rope in which the wire is preformed to fit the twists in the strands and the

strands preformed to fit the twist in the rope. This is sold under various trade names, but is generally known as preformed rope. This type of rope does not have a tendency to unlay. In fact, a strand may be taken out of a section and a wire taken from the strand. These may be returned to their original positions in the rope without disturbing the construction. These brands should not be confused with the non-rotating types.

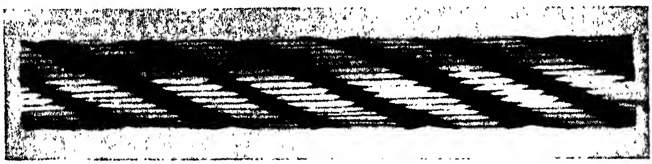


Fig. 329.—Partly worn regular-lay round-strand rope.

Fig. 330.—Partly worn Lang-lay round-strand rope.

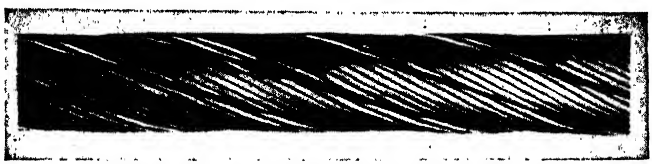


Fig. 331.—Partly worn flattened-strand rope.

A right-lay regular-lay construction is the one commonly used. In some cases left-lay ropes are used, such as for oil-well drilling ropes. For some elevator and hoist applications, left-lay is used in combination with right-lay rope, to produce a non-rotating combination.

Non-rotating Ropes.—As wire rope is commonly constructed, it will untwist if allowed to support a free load; in other words, it will rotate the load. There are non-rotating ropes made, but these are special constructions, one of which is shown in Fig. 332. This rope contains eighteen strands of seven wires each. The center of the rope has six strands left-lay Lang-lay about a hemp center. Around the center strands are twelve strands placed right-lay regular-lay. From this it will be seen

that the two layers tend to twist in opposite directions and prevent rotation.

Figure 333 shows a rope construction, the strands of which are twisted alternately left and right. Thus, when the strands are laid into a rope, they give a combination Lang and regular lay. When the rope is loaded, one lay tends to twist in one direction, while the other has the opposite effect and prevents rotation. There is a flat-strand-rope construction *J*, Fig. 327, that is made non-rotating by using alternate strands twisted in opposite directions, giving a combination regular and Lang lay. The

Fig. 332.—Two-layer combination Lang and regular-lay non-rotating rope.

Fig. 333.—Single-layer combination Lang and regular-lay rope.

chief use for these ropes is on conveying machinery, but they are mentioned here as interesting constructions. In the foregoing only a few of the more common types of rope have been considered, particularly those that have been used for elevators.

Measuring Size of Ropes.—If the diameter of a rope is not known, it will have to be measured. Some wire ropes are made so that their external surface is almost a true circle, in which case they have practically one diameter. For the ropes generally used on elevators this is not true, and there is considerable difference between their maximum and minimum diameters. The maximum diameter, Fig. 334, is the correct one to use when specifying wire rope. In other words, the diameter of a rope is the diameter of the minimum circle through which it can be passed.

A used rope will have a smaller diameter than it had when new, due to the bedding of the strands into the hemp center, to

stretching and to wearing of the strands. The sizes of hoisting ropes between 2-in. and $\frac{5}{8}$ in. diameter are generally in steps of $\frac{1}{8}$ in. If the diameter of an old rope is found to be $\frac{11}{16}$ in., this dimension is $\frac{1}{16}$ in. less than $\frac{3}{4}$ in. and greater than $\frac{5}{8}$, therefore it will be safe to assume that the rope was $\frac{3}{4}$ in. in diameter when new. Below $\frac{5}{8}$-in. in diameter, wire rope changes sizes in $\frac{1}{16}$-in. steps. For elevator service the sizes most commonly used for hoisting purposes are $\frac{1}{2}$ and $\frac{5}{8}$ in. in diameter or larger. Operating and governor ropes are usually $\frac{1}{2}$ in. or less in diameter. It is

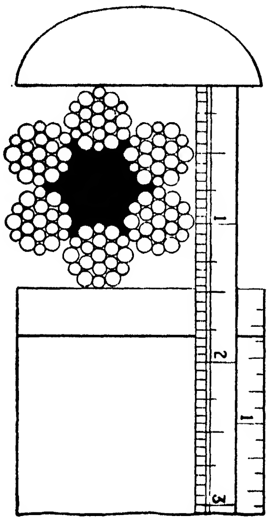


Fig. 334.

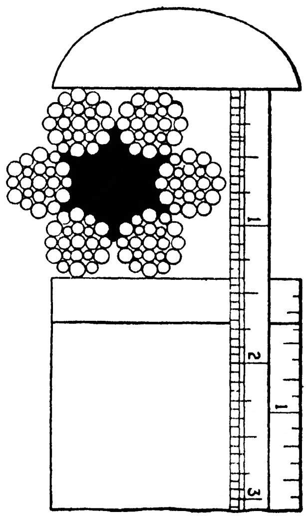


Fig. 335.

Fig. 334.—Correct diameter of wire rope.
Fig. 335.—Incorrect diameter of wire rope.

important that the correct size be selected, since an oversize or undersize rope will have a short life.

Rope Constructions Used on Drum-type Elevators.—Present tendencies seem to be toward the use of either the Warrington or the Seale types. Iron ropes of the 6 × 19 regular or Warrington constructions at one time were used almost exclusively for hoisting, counterweight and governor service on drum-type machines. They are still in wide use, but for drum-counterweight ropes on basement-type installations 6 × 37 or 8 × 19 mild steel is also used with satisfactory results. On these machines the counterweight ropes have a reverse bend in them as they lead off the drum and up the hoistway (see Fig. 64). In some cases this bend is short, but even under the most favorable

circumstances a reverse bend fatigues the wires in the rope faster than when all bends are in the same direction. Experience with 6×37 or 8×19 mild-steel ropes for these conditions has shown good results. Mild-steel ropes of the 6×19 construction are sometimes used for car-hoisting service.

Ropes Used on Traction Elevators.—In general, drum-type elevators are used on comparatively short rises, and run at slow speeds in service where they are not in continuous operation. As a result car mileage per year is comparatively small and the ropes may operate for ten years or more before replacement is necessary. With traction machines conditions are in general quite different from those for the drum type. Cars frequently operate at high speeds and are in continuous operation for nine or ten hours per day, consequently car mileage per year is high and ropes wear accordingly. Traveling 10,000 mi. or more per year is not uncommon for high-rise express cars. To increased wear and fatigue due to high yearly car mileage must be added effects of slippage and wedging of the ropes in the traction-sheave grooves. These conditions impose severe service on the ropes of traction machines.

For this service mild-steel ropes of various constructions are used, iron being unsuited. Mild-steel ropes are sold under various trade names, such as traction steel, special traction steel, toughened steel, etc. All, however, are made of a steel specially treated to make it suit the service conditions existing on traction elevators. Warring-type ropes have been used extensively on traction machines, but there is a tendency toward more flexible constructions. One manufacturer recommends, for full-wrap traction machines with sheaves over 29 in. in diameter, a 6×19 construction with six small spacer wires in each strand, making a 6×25 construction. For full-wrap traction machines with sheaves under 30-in. in diameter, all V-grooved-type traction and machines with 2 to 1 roping, an 8×19 Seale construction is recommended. All these ropes are made of a special traction steel. These recommendations are similar to those of another manufacturer making a toughened-steel rope.

Practice appears to be to the use of more flexible ropes, such as the 8×19 and 6×25 Seale constructions. These give a flexible construction with large wires on the outside of the strands to stand wear, and some manufacturers recommend this construction for practically all traction elevators.

Governor Ropes.—Until recently, practically all governor ropes were 6 × 19 or 6 × 42 iron. Mild-steel ropes of the 6 × 19 and 8 × 19 constructions are now being used quite extensively. The tail rope, connecting the drum on wedge-clamp-type safeties to the governor cable, is frequently made of bronze. This piece of rope is seldom in use and, if not looked after, may become badly rusted and weakened. Using bronze rope for this service eliminates the rust hazard, so far as the rope is concerned. Of course, if the safeties are allowed to become

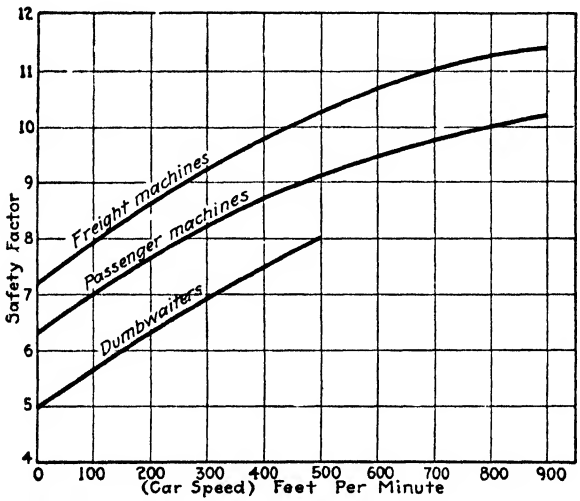


FIG. 336.—Factors of safety for hoisting ropes, based on the Standard Code for Elevators. The code recommends for traction-machines factors of safety 25 per cent in excess of the values given in these curves to allow for wear on the ropes.

rusted so that they cannot be applied, a bronze tail rope is of little use.

Compensating Ropes.—For compensating cables both 6 × 19 and 8 × 19 steel or iron constructions are used.

Regular-lay Right-lay.—Regular-lay right-lay is the one usually recommended for elevator service. Although Lang-lay rope offers a greater wearing surface to the sheave grooves, it is more difficult to handle than regular lay, and has not come into general use for elevator service.

The strength of rope does not usually come into the problem of selection. As the equipment is usually designed, the safety factor of the ropes is above that recommended by the Safety

Code for Elevators. These factors of safety are shown by the curves, Fig. 336.

Twenty Causes of Reduced Wire-rope Life.—Elevator rope life depends upon a multitude of factors and may extend over periods ranging from a few months to fifteen or twenty years. Although it is quite general practice to express life of wire ropes in terms of the time they have been in service, this method is not so accurate a measure as car mileage. In many of the better operated buildings recorders are installed on the elevators and a record kept of car mileage, and rope life is based on these records. Car mileage is not, however, always a measure of rope mileage, since on two-to-one-roped traction machines the rope speed is twice the car speed. With such installations it is necessary to multiply the car mileage by two to obtain the hoisting-rope mileage, which is the measure of the service rendered by these ropes.

There are many ways of roping-up elevator machines, as shown in Chapter IV and they all have an influence on rope life. On the full-wrap type traction machine, Figs. 70 and 71, the ropes make the two half-wraps over the traction sheave and one half-wrap around the secondary sheave. That is, the ropes make three 180-deg. bends all in the same direction. On the V-grooved type traction machine, Fig. 74, the ropes make only one 180-deg. bend, but they are subjected to a wedging action in the grooves. The single bend in the V-grooved sheave is apparently not any more severe on hoisting ropes than the three bends that obtain with U-grooved sheaves on the full-wrap type of machine.

On the two-to-one-roped traction machine, Fig. 73, the ropes travel twice as fast as the car, consequently, as measured in car miles, the ropes have a much shorter life than for the one-to-one-roped machines, where the car and ropes have the same speed.

On basement-type drum machines the counterweight ropes come off the top of the drum and make a reverse bend around a vibrating sheave to go up the hoistway, as previously mentioned.

On some of the installations in low-ceilinged basements it is necessary to locate this sheave close to the drum so that the ropes bend almost 90 deg. Such a reverse bend is conducive to short rope life and should be avoided where possible.

Wire ropes wear out from two causes: (1) a reduction in area produced by wearing of the individual wires and (2) breakage of the wires. In elevator service the latter is the cause for con-

demning practically all elevator ropes. From this the conclusion might be drawn that in general there has been a tendency to use elevator ropes that were too stiff for the service. In present-day practice the tendency is toward the more flexible 6 × 25 and 8 × 19 instead of the 6 × 19 construction, which was used at one time almost exclusively.

All elevator ropes are constructed with a hemp center. If the hemp center happens to be undersized or does not possess sufficient density, after the ropes are put into service the strands may work together and cause a large friction component between them as the ropes bend around the sheaves. This may set up stresses in the surface wires of the strands that will cause them to fail after a short service period. The hemp center in the rope should be of the proper diameter and of sufficient rigidity to support the strands in their correct relation. It should also be well lubricated.

It is not recommended to store ropes for a long time before using them, as there is danger of the lubricant drying out and moisture working into the ropes. In one case in mind, where rope had been stored for a long time, only a few months' service was obtained before they had to be renewed.

The speed of the ropes probably has little direct effect on their life when measured in miles of travel, except as it has a bearing on other factors. Rope speed may lead to wrong conclusions if the rope life is expressed in time. On slow-speed elevators the ropes may have a life of eight or ten years or longer. On a high-speed elevator the same ropes may last two years. In point of years' use this does not look very good for the high-speed ropes. If the rope mileage of the two machines is compared, it will probably be found that the mileage for the high-speed ropes greatly exceeds that for the slow-speed. In other words, the high-speed ropes are giving longer service. The difficult part of this comparison is to find slow-speed machines on which accurate mileage records are kept.

The material in the sheaves should be harder than the ropes, or the sheave grooves will wear too fast. This is a problem of design and one that the user has little control over, except to see that the sheave grooves are in good condition when a new set of ropes is installed.

Relation of Drum and Sheave Diameters to Rope Diameter. It is recommended that the sheave or drum diameter be as large

as possible, consistent with other conditions. It is preferred not to have traction sheaves less than 28 in. in diameter or about 40 rope diameters. Larger diameters than this will be favorable to rope life. When they bend around the sheaves or drum, the stress is normally reduced on the side of the ropes in the grooves and increased on the outside. The smaller the sheave the more severe this action becomes on the ropes, with a consequent shortening of their life.

The conditions of the sheave grooves have a marked effect on the life of hoisting ropes, particularly on traction machines. If the U-shaped grooves are worn to fit old ropes, a new set will wedge into the grooves. This wedging action tends to distort the ropes and cause fatigue and breakage of the wires. Since the grooves are generally not all worn to the same tread diameter, some of the ropes must travel faster than others. To accommodate this difference in rate of travel some of the ropes must slip. If they wedge into the grooves, the difference in loading of the ropes before slippage occurs will be increased and may cause excessive stresses to develop in some of them. As the surface wires must resist the forces that cause slippage, they may be stressed until actual breakage occurs.

When the hoisting ropes are to be changed on a machine, the grooves in the sheaves should be checked, and if found undersize or of unequal tread diameter, they should be put in proper condition. If more attention were given to this feature of elevator operation, the life of hoisting ropes would be greatly increased in many cases.

Automatic Equalizers on Elevator Ropes.—Equal tension should be maintained in the hoisting ropes. This is difficult, since one rope may have a tendency to stretch more than another or the grooves in the sheave may not have exactly the same tread diameter. It is becoming quite general practice to use equalizers on the hoisting ropes of traction machines. Figure 337 shows an Evans equalizer installed on a car's crosshead. Each pair of ropes connect to the ends of an equalizing bar. These bars connect to sheaves attached by an equalizing rope to a plate under the car's crosshead. This arrangement allows the load to equalize between the different cables, and it also tends to compensate for any difference there may be in the tread diameter of the grooves in the traction sheaves. If the cables tend to stretch unequally, this can be easily detected on the equalizer

and their length adjusted before they become unequally loaded. The L'Code equalizer, Fig. 338, is a bar type equipped with specially designed roller bearings. In the six-rope design shown, the ropes connect to the ends of three equalizing bars B_1, B_2, and B_3. Bar B_2 connects to the center of equalizing bar B_4. Ends of this bar connect to one end each of two other equalizing bars fulcrumed at F and F_1. Bar B_1 connects to one end of the bar fulcrumed at F_1 and B_3 to bar fulcrumed at F. Equalizing equipment is attached to plates by fulcrum shafts F and F_1, and

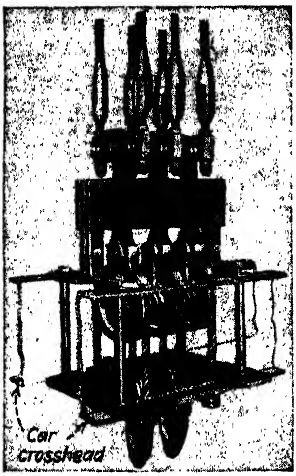


Fig. 337.—Evans elevator-rope equalizer.

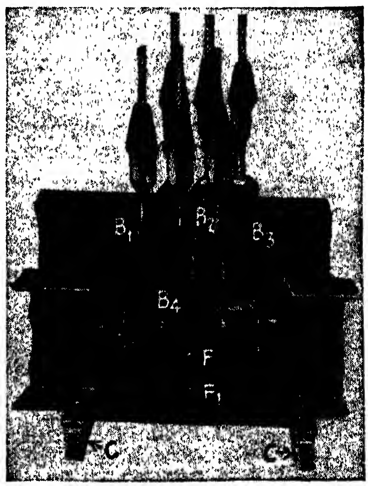


Fig. 338.—L'Code elevator-rope equalizer.

these plates support the car by two bars C that pass through them under car's crosshead. Ropes are thus free to equalize the load between them. Since each of the 18 fulcrum and connection pins is equipped with a roller bearing specially designed to have low friction, a small differential in rope loading causes the equalizer to function and distribute load equally on ropes.

Automatic equalizers are also applied to compensating ropes with satisfactory results. The life of these ropes are increased and their operation improved by the use of equalizers.

Experience has shown that unequal loading of ropes due to excessive stretch of some of them has been the cause of short rope life in more cases than is generally supposed.

It is necessary that the ropes lead off the sheave without rubbing one side of the grooves. This applies more particularly

to the sheaves on drum-type machines. One of the bearings worn on an overhead sheave would throw it out of line. If the shaft on which the vibrating sheave travels is not kept well lubricated, the sheave will lag on the shaft and throw the ropes out of line with the grooves as they come off the drum and will cause unnecessary wear on them.

Ropes on a high-rise car will have a longer life in car miles than those on a low-rise car. This is to be expected, since the high-rise car makes fewer trips per car mile, and this means less bending of the cables around the sheaves and less wear on them.

In the Union Central Life Insurance Building, Cincinnati, the high-rise cars travel about 400 ft. and the low-rise cars about 240 ft. Up to Nov. 1, 1927, the four high-rise cars had used 15 sets of hoisting ropes. These ropes had an average life of about three years and an average mileage of 25,567. The eight low-rise cars used 24 sets of ropes which had an average life of about 3½ years, but the average car mileage per set of ropes was only 15,425 miles. Rope life varies over a wide range and in a few instances has been up around 90,000 mi. In the Municipal Building, New York City, on sheaves 42 in. in diameter a rope life of over 165,000 mi. has been obtained with 8 × 19 ropes. This is unusual and can be accounted for by the large diameter of the sheaves.

Starting and Stopping the Car Effects Rope Life.—The schedule on which the car operates affects rope life. When the car is started and stopped the ropes are stressed above normal owing to the effect of acceleration and retardation. The change in loading caused by starting and stopping the car tends to fatigue the wires in the ropes and causes them to break. This is one reason why the ropes on a car in local service will have a shorter life than one in express service, even when both have the same rise.

Inching the car to make a landing also affects the life of the ropes. This is caused in a number of ways. One is the result of the increased loading of the rope when the car is started and stopped; another is the increased bending of the ropes. A car on the down trip is stopped below a floor. To bring it level with the floor the machine is reversed and a section of the ropes wound back on the drum. This section has been bent twice, once when the car went below the floor and once to bring it level with the floor. A third bend is put into this section of the ropes

when the car again starts on its down trip. From this it is seen that a section of the ropes at the sheave corresponding to the position of the car at the floor is bent three times, owing to one false stop. This section would have been bent only once if the car had been stopped level with the floor on the first trial. The sections of the ropes that are wound on and off the sheave owing to jockeying the car at floors will generally be where the ropes fail first. The operator in the car is therefore a factor in the life of the ropes.

Effects of Brake Adjustment.—If the brake is adjusted to stop the car too quickly, the ropes are subjected to unnecessary stresses. On the other hand, if the brake allows the car to slide, there will be an increased number of false stops with increased bending of the ropes, as previously explained. A poorly adjusted brake adversely affects the ropes.

In a damp atmosphere or where there are acid fumes in the air, the ropes may require lubrication to prevent them from rusting or corroding. When made they are well lubricated, and under normal conditions this lubrication may be sufficient to last for their life. When they bend around the sheaves, the strands have a certain movement in relation to each other, as also do the wires in the strands. Unless the ropes are properly lubricated the wires will tend to wear each other, and the increased stresses may cause breakage of the wires.

When Ropes Should Be Renewed.—Another factor in the life of ropes is the judgment of the man who condemns them. There is no method by which the condition of a set of ropes may be exactly appraised. A general rule is to condemn the ropes when six contiguous wires are broken in one strand. The conditions under which the ropes operate must also be taken into consideration. One inspector may order the ropes changed when another would allow them to run awhile longer. On account of the many factors that affect a rope's condition and that cannot be evaluated, there is good reason for a difference of opinion as to when ropes should be condemned.

Much has been said on the reserve strength of ropes. The high breaking strength developed by ropes that have been condemned has led some competent rope engineers to feel that there is a tendency to condemn ropes too soon. Even with the present liberal attitude on the side of safety there have been rope failures that are difficult to account for. Until some means is available

whereby the reserve strength of ropes can be determined while they are in service, it will be well to continue to error on the side of safety.

Putting Sockets on Wire Rope.—A method of socketing a cable ordinarily used by elevator construction and repair mechanics is shown in Fig. 339. The socket is slipped over the cable, large end last, as at *B*. The cable is then tightly served with binding wire a distance from the end equal to the length of the socket plus $2\frac{1}{2}$ times the diameter of the cable, as at *D*, after which the end serving is removed and the six strands are fanned out as far as the remaining serving. The hemp center is cut away, and each

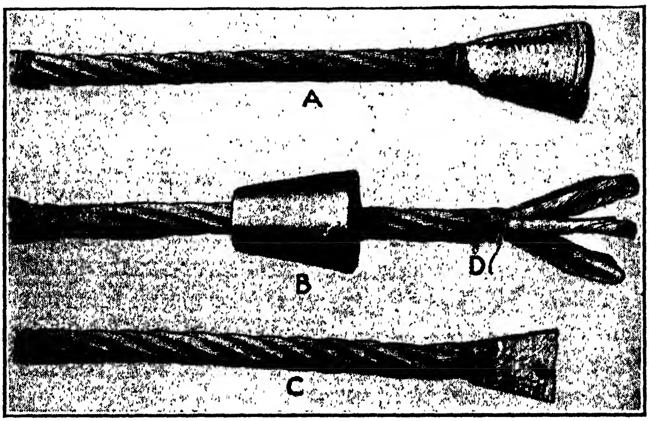


Fig. 339.—Turned-in method of socketing elevator ropes.

strand is bent back and inward on itself, bringing the ends close to each other in the center, and the socket is pushed up tightly over the upset end. Care must be exercised to make the bends of the strands as even as possible and to avoid driving one or more of the strands further into the socket than others, as such a procedure may result in what is known as "high strands," and abnormal wear develop. The small end of the socket is then plastered with fireclay or wrapped with waste and tape, to prevent the escape of molten metal, and melted babbitt, heated just sufficient to char a pine shaving, is poured into the large end of the socket.

The babbitt does not necessarily solder or alloy with the cables, but merely fills the crevices between socket and cable and between the strands, acting as a binder to hold the various parts in place, making a reliable piece of work which will not pull out. Figure

339*A* shows such a job with the socket removed, and Fig. 333*C*, a similar job sawed through lengthwise.

A method of socketing advocated is shown in Fig. 340. The cable is served the length of the socket from the end, with two extra servings below this, and the hemp center removed as far as the first serving. Each wire is separated from its neighbors and cleaned with kerosene, dried and then dipped into a solution half

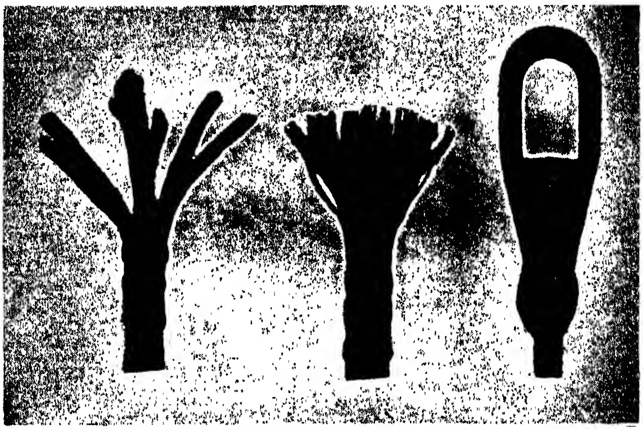


Fig. 340.—Straight method of placing sockets on elevator ropes.

and half muriatic acid and water, and shaken dry. The socket is slipped over the cable and the separate wires are fanned out equally in the basket. Fireclay is placed about the small end of the socket and molten spelter (pure zinc) is poured into the basket. This produces a splendid job, the zinc alloying with the wires of the cable, making a very homogeneous mass in the socket. Knowing the conditions under which most elevator cable socketing is done, many readers may prefer to ride in cars where the turned-in method, Fig. 339 is used, which is the one specified by the Safety Code for Elevators.

CHAPTER XXIV

SELECTING ELEVATORS FOR OFFICE BUILDINGS[1]

Traffic Peaks.—To determine the number of elevators required for all classes of service necessitates consideration of more than two hundred factors. When the problem is limited to a single class of service the number of elements involved is greatly reduced. The problem of providing adequate service in an office building divides naturally into two parts. The first is the number of passengers to be carried. It is customary to consider the five-minute morning peak of traffic as the controlling factor unless some peculiar conditions exist.

In a well-diversified office building the five-minute traffic peak will usually not exceed one-ninth of the building's population. When the tenancy is not so well diversified one-eighth of the population will be a more accurate estimate of the morning peak of traffic. In single-purpose buildings where all of the employees are required to report for duty at the same time, the peak may amount to one-third of the population. An installation calculated to care for normal requirements would be inadequate for such exceptional peaks of traffic.

Accurate, complete and comparable information regarding the flow of traffic in office buildings is very meager and building managers and superintendents would render a distinct service to others if they would obtain and publish data obtained from buildings over which they have supervision. Improvement in service will always result from a reduction of severe traffic peaks and these can often be reduced through intelligent supervision and cooperation from the tenants.

The morning traffic peak is used as the basis for calculating elevator requirements even though the evening peak is higher, because passengers congregating in the evening on the upper floors is not so objectionable as crowding at the first floor. Moreover, cars can be dispatched to individual floors in the evening and a greater number of passengers carried in a given period by this method. The population of a building will, of course, change

[1] Howard B. Cook supplied a large part of the material in this chapter.

with the rentable area per person and this varies from about 60 sq. ft. per person to about 150 sq. ft. per person, 100 being about the average.

Round-trip Times.—The second part of the problem is to select, from many available combinations of elevators, the most suitable for carrying the estimated number of passengers. The number of passengers carried in five minutes by an elevator is equal to the number of passengers per trip multiplied by the number of trips made in that time. The number of cars required is found by dividing the number of passengers to be carried, by the number carried per car.

The round trip time of an elevator is equal to the sum of a number of variable factors, some of which are difficult to put in the form of an equation. It is possible, however, to determine values for the various factors and to add them together to give a value for the round-trip time that will be consistent with observed results with a fair degree of accuracy. Round-trip time can be divided into the traveling time and time consumed by other factors. It is customary to add 10 per cent to the calculated round-trip time, when several elevators are operated in a bank, to cover time consumed because of the car being off schedule and other factors.

Probable Number of Stops.—Traveling time depends upon the normal car speed, the average of the rates of acceleration and retardation, the distance between stops and the number of stops. The probable number of stops made by an elevator is less than the number of passengers taken on at the first floor. If the number of persons per floor is the same for all the floors at which stops may be made and if the car always stops at the top floor, then the probable number of stops made on the up trip is found from the equation

$$\textit{Probable stops} = S - (S - 1) \times \left(\frac{S - 1}{S}\right)^P$$

where S equals the number of possible stops above the first floor and P equals the number of passengers taken on at the first floor. This equation was developed by S. G. Margles in 1922.

Figure 341 gives the probable number of stops made by an elevator on the up trip. Three speeds have been selected, namely; 8, 10, and 12 ft. per sec. which are equivalent to 480, 600, and 720 ft. per min.

Rates of Acceleration.—It will be assumed that the average of the rates of acceleration and retardation will be equal to 4, 5, and 6 ft. per sec. per sec., respectively. These rates are rather high and will be attained only with gearless equipment, variable-voltage control, and automatic stops. The distances required for the attainment of full speed with start and stop are 16, 20,

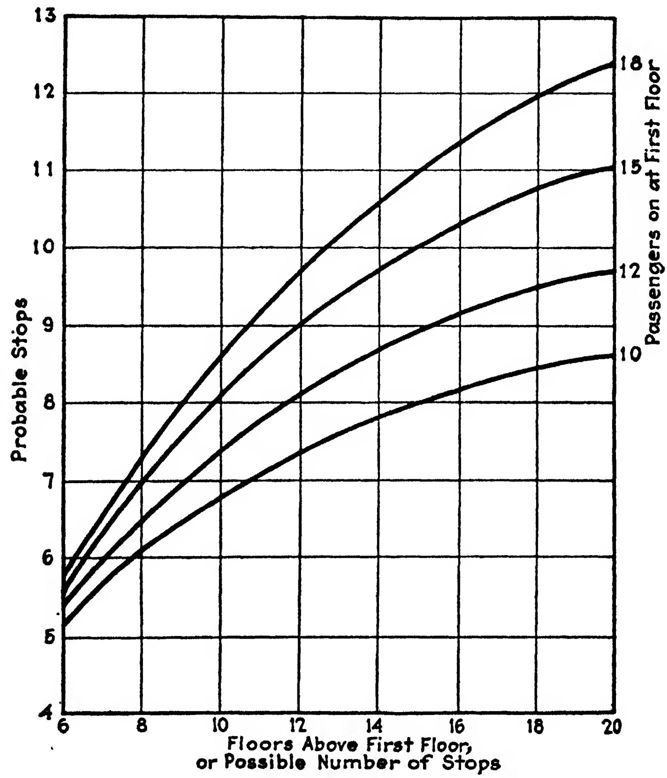


Fig. 341.—Probable number of stops made by an elevator on the up trip.

and 24 ft., respectively. (See "Rates of Starting and Stopping Elevators," *Power*, May 11, 1926.)

If the average distance between stops is less than the distance required to attain full speed, then the time per stop, in seconds, may be obtained by means of the equation

$$t = \sqrt{\frac{4S}{a}}$$

where S is the average distance in feet between stops and a the rate of acceleration.

When the distance between stops is greater than that required to reach full speed and stop the car then the time per stop in seconds may be found by adding the distance required to attain full speed and to stop the car to the distance between stops and dividing the total by the normal speed in feet per second.

It is assumed that, during the morning peak of traffic, the car will descend from the top floor with the operator only and without making stops while descending.

Time for Door Operation.—Time-consuming factors other than traveling time are door operation, passengers entering at the first floor and leaving at the upper floors. The time required for door operation is an important factor in modern-elevator service, as will be shown later, Figs. 344 and 345.

To show clearly the effect of this factor the round-trip time has been calculated for the three speeds selected with doors operating in 2, 3, and 4 sec. A door speed of 2 sec. for opening and closing is about the limit at the present time even with power-operated doors.

Time for Passengers to Enter and Leave Car.—It is assumed that the time required for passengers entering the car at the first floor is one second per passenger. The time required for passengers to leave the car at the upper floors is influenced by the degree of crowding within the car and to reduce the effect of crowding, cars are not loaded to capacity during the morning peak of traffic. The effect of door width, rapidity of door operation and car shape upon the rate of passenger movement should be thoroughly investigated and the results published. The time required by passengers leaving the car at the upper floors is taken from curves of average observed results. (Fig. 342.)

Round-trip-time Curves.—Having established the values of the various factors affecting the round-trip time of an elevator it is not difficult to determine the round-trip time and the number of passengers carried in 5 min. by any equipment.

Curves showing the round-trip time and the number of passengers carried per car in 5 min. have been drawn for 10, 12, 15, and 18 passengers per trip corresponding to the number of passengers to be carried during the morning peak of traffic by cars having capacities of 2,000, 2,500, 3,000, and 3,500 lb., respectively (Fig. 343). These curves are calculated for a first floor height of 18 ft., other floors 11 ft.

It will be noted that the curves, Fig. 343, are not drawn to rectangular coordinates but the lines, indicating the number of floors, are inclined. This arrangement shortens the curves and spreads them farther apart thus making them more readable. The values for the points on the curves are calculated as follows:

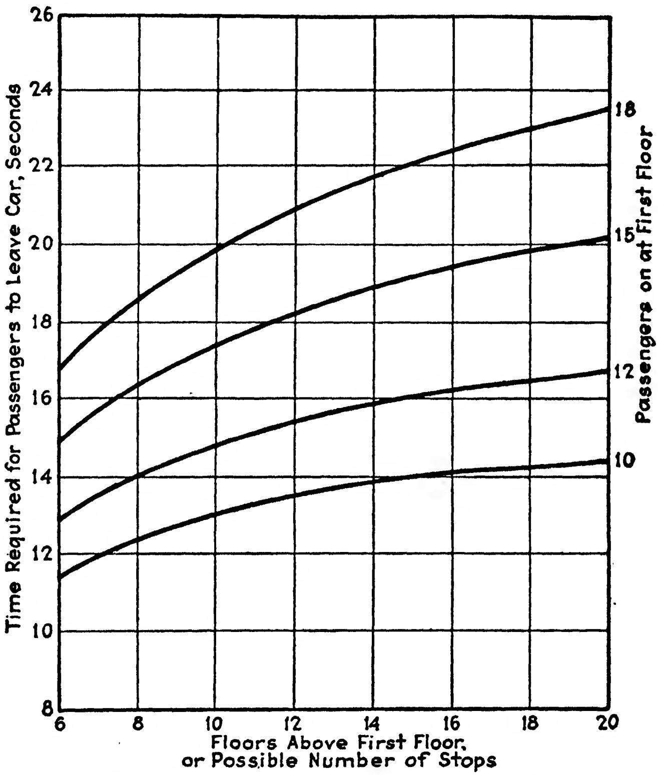


FIG. 342.—Time required for passengers to leave the car.

The probable number of stops made by an elevator ascending with 18 passengers taken on at the first floor with 20 possible stops or 20 floors above the first is 12.4 as taken from Fig. 341. On this figure, take the possible number of stops, 20; run vertically to the 18-passenger curve and then horizontally to the probable number of stops scale and the value 12.4 will be obtained. The time required to take 18 passengers on the car at the first floor allowing one second per passenger is 18 sec.

The car rise is 19 floors plus the distance from the first to the second floors, or $(11 \times 19) + 18 = 227$ ft. Then the average

distance between probable stops is $227 \div 12.4 = 18.3$ ft. At 720 ft. per min., the car is traveling 12 ft. per sec. To start from rest and accelerate to a speed of 12 ft. per sec. at a rate of 6 ft. per sec. per sec. will require $12 \div 6 = 2$ sec. The distance traveled during acceleration is

$$D = 0.5\,at^2 = 0.5 \times 6 \times 2 \times 2 = 12 \text{ ft.}$$

A similar time and distance will be required to stop, so that accelerating the car to full speed and again stopping will require $2 + 2 = 4$ sec., and the distance in which this is done is

$$12 + 12 = 24 \text{ ft.}$$

This distance is greater than the average between stops, consequently, the car does not obtain full speed before it will begin to slow down to make the next stop. The average time per stop can then be found by formula
$t = \sqrt{\dfrac{4S}{a}}$, and is $t = \sqrt{\dfrac{4 \times 18.3}{6}} = 3.49$ sec., so that the probable actual running time required by the car to make the up trip is $3.49 \times 12.4 = 43.3$ sec. The average number of doors to be operated on the up trip is equal to the number of stops plus one at the first floor, or a total of $12.4 + 1 = 13.4$. Allowing 3 sec. per door to open and close gives a total time of

$$13.4 \times 3 = 40.2 \text{ sec.}$$

For the 18 passengers to leave the car at the floor stops requires 23.5 sec., as obtained from Fig. 342.

The time required to make the down trip without intermediate stops is equal to the starting and stopping time plus the time that the car runs at full speed of 720 ft. per min. The time required to accelerate to full speed and retard the car to rest has been found previously to be 4 sec. and the distance in which this is done is 24 ft. The distance traveled at 12 ft. per sec. is $227 - 24 = 203$ ft. and the time required to travel this distance is $203 \div 12 = 16.9$ sec. Then the time required to make the down trip without intermediate stops is $4 + 16.9 = 20.9$ sec.

To make the round trip, the total time is equal to the time (18 sec.) required for the passengers to get on at the first floor; plus the running time (43.3 sec.) on the up trip; plus the time (40.2 sec.) required to open and close the doors; plus the time (23.5 sec.) taken by the passengers to get off the car at the differ-

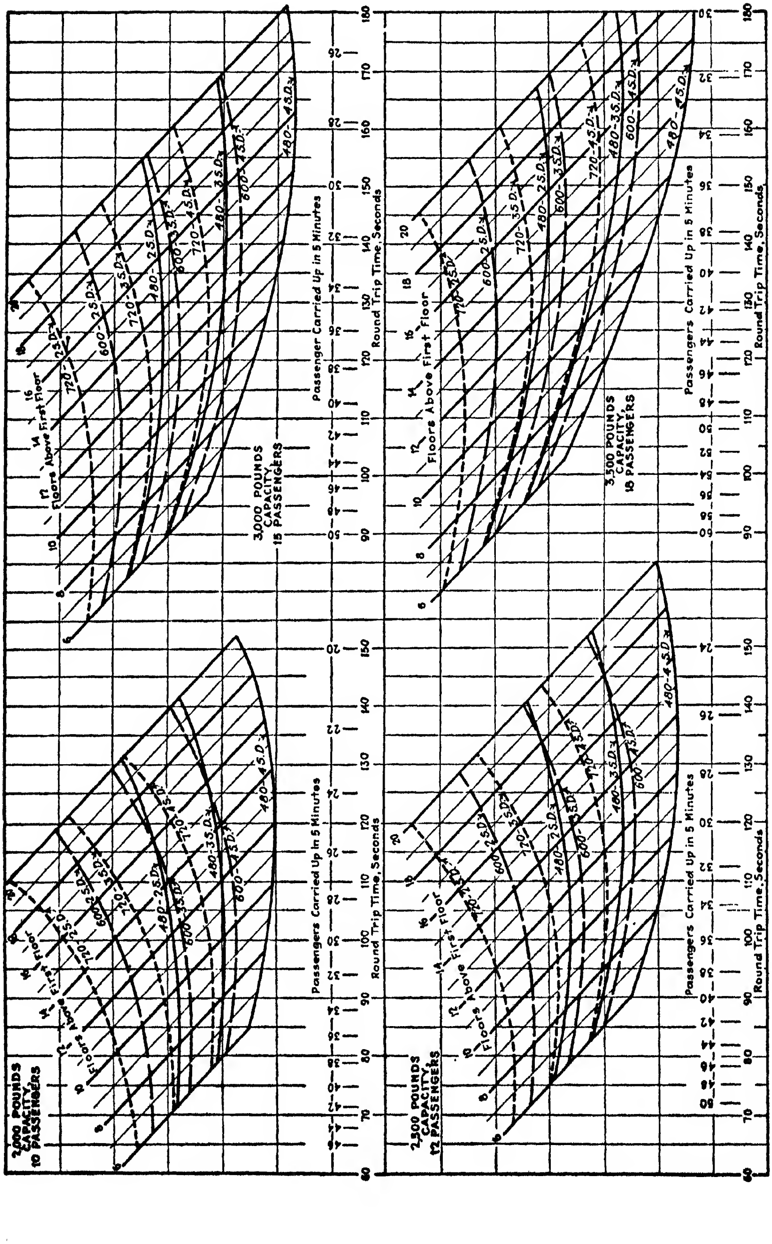


FIG. 343.—Curves for determining the round-trip time and the number of passengers carried by an elevator.

ent floors; plus the time taken (20.9 sec.) for the down trip; or $18 + 43.3 + 40.2 + 23.5 + 20.9 = 145.9$ sec. Adding ten per cent to this value as a safety factor give 160.5 sec. as the total round-trip time. This value will be found on the group of curves in the lower right-hand corner Fig. 343, which is for a 3,500-lb., 18-passenger car, operating at 480, 600 or 720 feet per minute.

The identification marks on the curves, Fig. 343, such as 720—3 S.D., 600—2 S.D., etc., indicate a car speed of 720 ft. per min. with 3 sec. landing doors, and a 600-ft.-per-min. car with 2-sec. landing doors, etc.

In the problem worked through there are 20 floors above the first, 18 passengers get on at the first floor, the car speed is 720 ft. per min. and the landing doors require 3 sec. to open and close. Applying these data to the curves in the lower right-hand corner, Fig. 343, find the diagonal line representing the floors above the first, follow this line until it intersects the car speed and landing door curve (720—3 S.D.) then drop vertically down to the round-trip time scale and the value 160.5 is obtained. A second scale is provided that gives the number of passengers that can be carried up in 5 min. On this scale 34 is obtained as the number of passengers carried up in 5 minutes.

As a further illustration of how to use the curves, Fig. 343, assume a 2,500-lb., 12-passenger car operating at 600 ft. per min. with 3-sec. landing doors, that serves 14 floors above the first. Find the floor line marked 14 and follow it until the 600—3 S.D. curve is intersected, then drop vertically down and the answer 118 sec. is found to be the time required for a round trip, when going up with 12 passengers in the car and coming down without stopping. The number of passengers carried in 5 min. is given as about 30.

Suppose that it has been determined that the morning peak of traffic in a 21-story building (20 floors above the first floor), all floors having the same population, would amount to 150 passengers in 5 min. This would be one-ninth of a population of 1,350 persons corresponding to a building of 135,000 sq. ft. of rentable area with a density of one person per 100 sq. ft., or 6,750 sq. ft. per floor.

The table shows the combinations available for serving this building as selected from the curves of Fig. 343. Any of the combinations in the table would adequately serve this building but with varying degrees of excellence of service (see Fig. 346).

When the number of available combinations has been narrowed down by the consideration of this factor then the final selection is made after considering first cost, operating cost, building space required, and many other factors of varying importance.

Various Elevator Combinations for Serving a Given Building

Car and door speeds*	Number of passengers per trip	Round trip time, sec.	Passengers per elevator in 5 min.	Number of elevators	Interval between cars, sec.	Class of service
600—2 S.D.	10	119	25	6	20	Excellent
720—3 S.D	10	121	25	6	20	Excellent
600—4 S.D.	10	140	21.4	7	20	Excellent
720—2 S.D.	12	120	30	5	24	Excellent
720—4 S.D.	12	144	25	6	24	Good
720—3 S.D.	15	150	30	5	30	Good
720—2 S.D.	18	144	37.5	4	36	Good
480—3 S.D.	18	180	30	5	36	Fair

* The first figures in this column are car speeds in feet per minute and the second figures give the time to open and close the landing doors. Thus 600—2 S.D. indicates 600 ft. per min. with 2-sec. landing doors.

It is important to consider that if the number of elevators to be installed is reduced to a minimum by the use of high-speed cars, automatic control, and power-operated doors, then any opportunity to improve the service or to care for additional traffic is practically eliminated.

To increase the speed of an installation above that for which it was designed is difficult and usually has very little influence on the service.

Cars for Express Service.—The curves, Fig. 343, can be used for express service by the simple addition of the time required to travel up and down the increased distance from the first floor to the first local-floor stop.

An elevator having a speed of 720 ft. per min. and carrying 18 passengers per trip in a 21-story building would have a round trip time of 160 sec. with 3 sec. doors and would carry 34 passengers in 5 min. Eight such elevators in local service would carry 272 passengers in 5 min. and the interval would be 20 sec. The service would be classed as good.

Now suppose that two groups of 4 cars each are substituted for the 8 local cars and that one of the groups distributes passengers to the lower floors up to and including the twelfth floor or, eleven floors above the first floor. If 272 passengers are

carried to 20 floors, then 150 passengers will be carried to 11 floors and each of the 4 cars must carry 37.5 passengers in 5 minutes.

Referring to Fig. 343 we find that cars carrying 15 passengers per trip at a speed of 600 ft. per min. and with 3-sec. doors will be suitable for the local service. The round-trip time is 117 sec. and the interval between cars, which is always equal to the round-trip time divided by the number of cars in the bank, will be $117 \div 4 = 29$ sec. The service will be classed as excellent.

The other group of 4 cars will be used for express service and if the first stop is at the thirteenth floor the express run would be 139 ft. and the time to be added to the values on the curves for 720 ft. per min. is found by subtracting 18 ft. (The time required to travel 18 ft. from the first to the second floors is included in the values taken from the curves) from 139 ft. which leaves 21 ft. This distance is multiplied by 2 for the up and down travel and the total divided by 12 (720 ft. per min. equals 12 ft. per sec.) and the result is $121 \times 2 \div 12 = 20.2$ sec. This value is increased by 10 per cent as a safety factor and the total amount to be added is $20.2 + 2 = 22.2$ sec.

The number of passengers to be carried to the upper part of the building in 5 min. is 122, or $122 \div 4 = 30.5$ passengers per car. The round-trip time for 9 floors above the first with a 720-ft.-per-min. elevator carrying 12 passengers and with 3-sec. doors is 92 sec. and with 22.2 sec. additional for the express run the total round-trip time is 114.2 sec. The number of round trips in 5 min. is 2.62 and with 12 passengers per trip the number carried per car in 5 min. is 31. The interval between cars is $114.2 \div 4 = 29$ sec. and the service would be classed as excellent.

The arrangement of local and express cars reduces the cost of the installation and improves the service to the individual floors but the convenience to interfloor traffic is less. The improvement in service resulting from the express and local arrangement is due to the preselection of passengers at the first floor into two groups, which precludes a reduction in the number of stops, the number of door operations and the miles traveled. This arrangement also saves space in the building.

Rules for Elevator Selection.—There are no simple and easy rules for the selection of elevator equipment for a building, but by a process of cut and try it is possible to select the most suitable arrangement. There is no occasion for wide differences in equipment for buildings comparable in size and requirements

and it should be possible to select the elevator equipment for buildings of ordinary requirements without much difficulty.

Building owners, managers, and engineers can do much to limit the peaks of traffic and improve the service if the installation has been properly planned.

The selection of elevator equipment for a new building is necessarily based upon an estimated volume of traffic but the actual conditions are always different and never remain constant. The number of persons per floor is never the same for all floors and transient traffic varies widely. The solution of problems continually arising requires constant attention on the part of those responsible for the operation of the elevators if the best service is to be attained at the lowest cost.

An accurate knowledge of the capabilities of the equipment is important. The elevators should be operated with a varying number of stops per trip without door operation to determine the traveling time. Another series of tests should be made including door operation but without passengers to determine the time required for door operations and the round-trip time with varying numbers of stops and passengers under actual operating conditions should be recorded.

An accurate count of the passengers should be made and recorded at 5-min. intervals. Passengers up and passengers down should be recorded separately. Inter-floor traffic should be determined. Traffic counts should be made whenever conditions change sufficiently to influence the service.

It often becomes necessary to make extensive changes in an existing installation to improve the service. A very complete test and traffic count should precede such changes and the probable effect of each new factor should be calculated with great care before a final decision is made. In making the calculations the foregoing analysis and curves will be found helpful.

Hoistway-door Operation.—Hoistway-door operation time is an important factor in passenger elevator service. In round trip time the difference between two elevators having speeds of 600 and 800 ft. per minute, both making twelve stops per round trip in a twenty-story building is approximately 12 sec. If the doors on the 600 ft. per minute elevator are operated one second faster, per door, than those on the 800 ft. per minute elevator, the slower-speed elevator will have the same round-trip time as the faster one.

The time required in the operation of an elevator door depends upon the weight of the door, the width of the opening and the forces applied. The laws of motion can be used in this problem with definite results. Friction in a modern door hanger is very small and its influence may be ignored. It will be assumed that the door is accelerated to the mid position with a constant force and retarded from this point to the extreme position with an equal force. The equation $T = \sqrt{\frac{WD}{96.6F}}$, where W is the weight of the door in pounds, D the door movement in inches, and F the force in pounds, allows calculating the time T required for operating any sliding door, when the door movement in inches, the door's weight in pounds and the force applied are known. The equation also shows that the force required to operate a door in a given time varies directly as the weight of the door and directly as the width of the opening or the movement of the door. The force required varies inversely as the square of the time of operation. To reduce the time to one-half requires the application of four times the force. A single sliding door having a width of 48 in., a weight of 140 lb. and a force of 48 lb. applied to it, will open in a time $T = \sqrt{\frac{140 \times 48}{96.6 \times 48}} = 1.2$ seconds.

Two sets of curves are given to facilitate the application of the equation. Fig. 344 gives the value of $WD/96.6$ for doors of various widths and weights. Fig. 344 also gives the weight per square foot for doors 7 ft. in height. Fig. 345 shows the relation between the force required and the resulting time of operation. The curves are used as follows:

The ordinate in Fig. 344 representing a door 48 in. wide meets the abscissa representing a door weight of 140 lb. at the curve which represents 70 for the value of $WD/96.6$. The value 70 is then taken as an ordinate in Fig. 345 and at this value it is found that this door can be operated in 1.2 sec. with a force of 48 lb. The time of operation corresponding to other forces can also be found.

Biparting, or center-opening, doors consist of two panels moving in opposite directions. A door of this type having a total opening of 48 in. and a total weight of 140 lb. can be operated in 1.2 sec. with a force of 24 lb. or one-half that required to operate an equivalent single sliding door in the same time. A force of 48 lb. would operate the biparting door in 0.85 sec. The

time and force required to operate a biparting door are found by assuming that the door is equivalent to a single sliding door of equal total weight and half of the movement.

For example, the total opening width is 48 in. and the total weight of the door is 140 lb. This is the equivalent of a single door weighing 140 lb., moving 48 ÷ 2 = 24 in. To find the force required to operate the door in a given time, one-half of the door is considered at a time, or, in this case, one-half of the door weight 140 ÷ 2 = 70 lb. and moves 24 in. Assume an opening

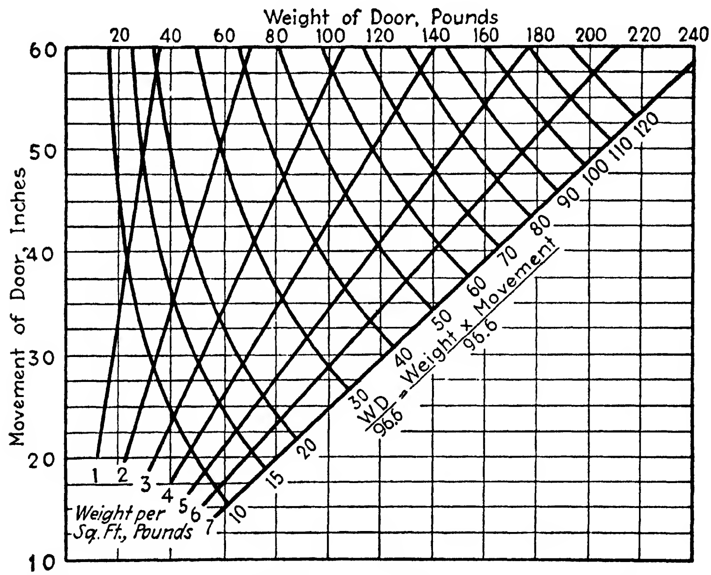


FIG. 344.—Chart giving weight and movement of elevator hoistway doors.

time of 1.2 sec., then, on Fig. 344, the ordinate representing a door movement of 24 in. meets the abscessa 70, the weight of one-half of the door, at the curve which represents about 17.5 for the value of $WD/96.6$. This value, 17.5, is for one half of the door. For the two halves it will be 17.5 × 2 = 35. Using 35 for an ordinate value in Fig. 345, it will be found to intersect the 1.2-sec. time line at a point corresponding to a force of 24 lb.

Two-speed or two-thirds doors must be considered as two single-panel doors. The slow-speed panel operates the same as a single-sliding door, but the high-speed panel moves double the distance that the slow-speed panel moves. A slow-speed

panel having a width of 24 in. and a weight of 70 lb. would require a force of 12 lb. to operate it in 1.2 sec. The high-speed panel would require a force of 24 lb. for complete movement in the same time.

The total force required to operate the two-speed door in 1.2 sec. is 36 lb. The two-speed door requires a 50 per cent greater force than the biparting door for operation in a given

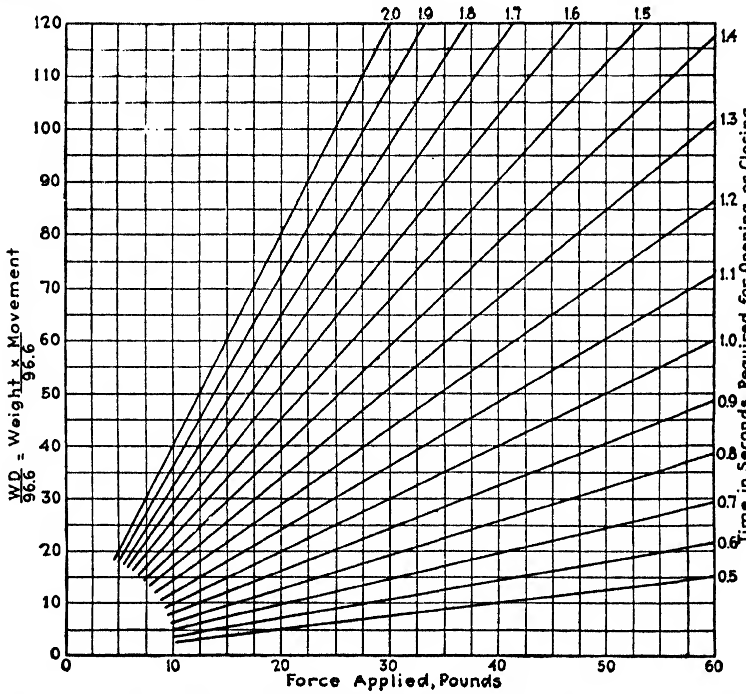


FIG. 345.—Chart giving force and time required for opening and closing hoistway doors.

time. Time of operation is the period required for opening or closing. The time required for the complete operation of opening and closing is found by doubling the values given.

Fig. 344 may also be used to determine the total weight of hoistway doors 7 ft. high when the weight per square foot is known. Assume a door 7 ft. high, 40 in. wide and weighing 6 lb. per square foot. To find its weight, follow the 6-lb. diagonal line up to where it intersects the 40-in horizontal, movement-of-door line; vertically above this intersection 140 lb. is read, the weight of the door.

When a manual door-operating device of the spring and dashpot type is used, the operator must apply considerable force to compress the spring in addition to the force required to accelerate the door. The spring absorbs the energy of motion as the door moves to the extreme position. When the door starts to close the energy in the spring accelerates the door until the dashpot brings the door to rest. The energy of motion during the closing movement is dissipated in the air that is forced from the dashpot.

In some of the power-operated devices attempts have been made to conserve the energy of motion in springs or lifted weights, this energy being used to assist in accelerating the door during the next operation.

If a door could be hung like a pendulum from a point, a considerable distance above the center of movement, it would be very easy to catch and hold the door at rest at the extreme positions. Such a door could be operated with very little force.

The danger of being struck by a heavy elevator door is a cause for fear on the part of the passengers. If a door has been accelerated by a constant force of 20 lb. for a distance of 24 in., the energy accumulated will create a force four times as great if an attempt is made to stop the door in a distance of 6 in. To stop this door in 3 in. would require a force of 192 lb.

If elevator doors are to be operated rapidly they should be made as light as possible, and adequate safeguards must be provided to protect the passengers against injury. It is possible that some arrangement of double doors will eventually be used whereby a very light door is closed quickly and a heavier door is closed leisurely after the elevator departs. The effect of door width and rapidity of door movement upon the time required for passenger transfer is a subject that deserves thorough investigation. Elevator service can be improved to a greater extent by improving the door operation than by increasing elevator speeds and at considerably less cost.

Standards of Elevator Service.—No definite standard has been formulated to measure the quality of elevator service. Statements have been made that service cannot be considered good if the interval between cars exceeds a certain arbitrary value, but in most cases the time required to make a round trip has been ignored.

The interval between cars in any bank of elevators is equal to the round trip time divided by the number of cars in the bank.

With four cars in a bank an interval of 20 sec. between cars would require a round trip time of 80 sec. With eights cars in a bank an interval of 20 sec. between cars would require a round trip time of 160 sec.

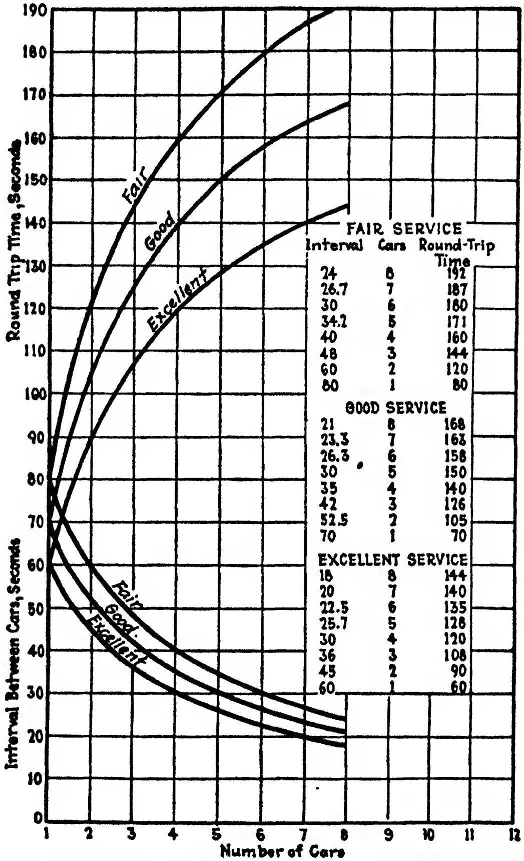


FIG. 346.—The curves and tables give values for determining the quality of elevator service.

The average passenger would wait in the hallway 10 sec. after pressing the button before a car stops, in either case. But the average passenger carried in a car, in the bank of four elevators with a round-trip time of 80 sec., would have a traveling time only half as long as the average passenger carried by one of the cars in the bank of eight elevators with a round trip time of 160 sec.

It is obvious therefore that the interval of time between cars is not the proper measure of elevator service. This measure is the time required to take the average passenger from the first floor to the average floor, including both the average waiting time and the average traveling time.

The average passenger waiting time is equal to one-half of the interval between cars, and the average traveling time is approximately equal to one-fourth of the round-trip time. Consequently, if one-half of the interval between cars is added to one-fourth of the round-trip time, the result will be a measure of the service regardless of the number of cars in a bank or the length of travel.

It is possible that this rule should be modified to some extent in those buildings where the cars stand for a considerable period at the terminals. In express service, also, the traveling time of the average passenger will be increased, because passengers are taken to and from a relatively small number of floors near the upper limit of travel. It will be contended that a reduction in waiting time is of greater relative importance than a reduction in traveling time, but this advantage is difficult to evaluate. A reduction in interval might also be considered of greater relative importance to interfloor passenger traffic.

The rule suggested is easy to apply and is sufficiently accurate for purposes of comparison. It remains to designate values to represent various degrees of excellence of service.

After considerable investigation of this subject, it has been determined that when one-half of the interval between cars plus one-fourth of the round-trip time is equal to 45 sec. the service may be classed as excellent. When the sum of these quantities is 52.5 sec. the service may be called good. When the sum is 60 sec. the service is only fair. The curves and tables, Fig. 346, give the round-trip time and the interval between cars for the three grades of service for various numbers of elevators in a bank.

In many buildings it is customary to shut down one or more of the elevators in a bank during the middle of the morning and afternoon, when the traffic is light. This practice has, in some cases, resulted in criticism of the service. By application of the rule for measuring elevator service it is possible to determine whether a car can be shut down without impairment of the service.

Suppose a building has six elevators in a bank operating at a round-trip time of 135 sec., which gives an interval of 22.5 sec.

This is excellent service. When the traffic decreases to such an extent as to make possible the maintenance of a round-trip time of 128 sec. with five cars the service is still classed as excellent, because the average passenger will be carried to the average floor in 45 sec., that is, $\frac{1}{2}$ of 25.7, the interval between cars, plus, $\frac{1}{4}$ of 128, the round-trip time in seconds, or $12.85 + 32 = 44.85$ sec.

INDEX

A

G

P

R

S